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A PROCEDURE FOR A PARTIAL SEISMIC REQUALIFICATION OF DARLINGTON CABLE RACEWAY

Report No. 91-48-K

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Mechanical Research Department
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ABSTRACT

Darlington cable raceway system was originally designed and seismically qualified by the Civil Engineering and Architecture Department (CEAD) using adequate quality raceway components. During the past few years, many concessions have been made to the manufacturer of the nuts used in the cable raceway assembly. The nuts received in the last few years were not adequate to support the loading conditions postulated in the original CEAD design and qualified in their test program. Some nuts were installed incorrectly because of their poor quality. An on-site inspection (by authors) revealed that the postulated loading conditions used in original tests may have been too conservative. The first natural frequency of the majority of the raceway appears to be much higher than the assumed 0.5 Hz used in the original qualification. Lower quality and misinstalled nuts may still be adequate for raceways having first natural frequency above 8.5 Hz. A test program is now underway to determine if this assumption is valid. Raceway will be tested at the station to identify runs having low first natural frequencies. These runs should be reinforced by bracing. If an adequate reinforcement cannot be provided in some parts of the raceway, low quality nuts should be replaced with higher quality (eg. Unistrut) nuts, or welded H3000 type brackets can be implemented. A more advanced analytical qualification procedure may be carried out on selected runs that have long trapezes or that are difficult to reinforce.

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EXECUTIVE SUMMARY

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Darlington cable raceway system was originally seismically qualified by the Civil Engineering and Architectural Department (CEAD). However, during the past few years, many concessions were made to the manufacturer of the nuts used in the cable raceway assemblies. Because of the reduced requirements combined with an inferior quality assurance program, some aspects of the raceway are not seismically qualified. The nuts received by the Darlington station in the last few years were of inferior quality. Many nuts could not properly fit into the struts. Even properly installed nuts could not support the loads used in the original test program conducted by CEAD. Based on the results of a brief Ontario Hydro Research Division test program, these nuts need to be replaced or requalified. The brittle brackets supplied to the station may not be able to support the CEAD postulated loads either. This report outlines the proposed partial requalification procedure for the raceways containing inferior or misinstalled nuts. The requalification may include testing, raceway modification and analysis.

An on-site inspection revealed that the loading conditions used in the original test program may have been too conservative. The first natural frequency for the majority of the raceway appeared to be well above the 0.5 Hz used in the original qualification. The low quality and misinstalled nuts may still be adequate for raceways having higher natural frequencies. A test program is proposed to determine an acceptably high natural frequency. The raceways will be tested to find runs that have low first natural frequencies. These runs should be reinforced by bracing. In parts of the raceway where adequate reinforcement cannot be provided, faulty nuts may be replaced with higher quality (eg. Unistrut) nuts or a welded H3000 type brackets can be introduced. A more advanced (analytical) qualification procedure can also be used to qualify selected runs that have long trapezes or that are difficult to reinforce. Several special cases will be considered such as cantilevered trays, very long trapezes and floor supported trapezes. Problems associated with the interaction between Class 1 and 2 raceways and between Channel A and B raceways will also be addressed.

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NOMENCLATURE

DBE:	Design Base Earthquake - an engineering representation of the seismic event expressed as response spectra or time histories and is used for seismic qualification of structures and equipment.
Damping Ratio:	The ratio of the damping coefficient to the critical damping coefficient for a single-degree-of-freedom oscillator or a normal mode of vibration.
FRS:	Floor Response Spectrum - a response spectrum of the motion of a particular floor or elevation in a structure
Rigid Equipment:	For the purpose of seismic design and seismic qualification, rigid equipment refers to equipment whose lowest natural frequency in the "as mounted" condition is greater than the rigid frequency
Rigid Frequency:	A frequency equal to or greater than 33 Hz, unless the ground motion or floor motion characteristics warrant otherwise
RS - Response Spectrum:	A graphical display of the maximum responses, plotted against natural frequency, of a family of single-degree-of freedom oscillators having a range of natural frequencies and specified damping, when subjected to a specified support motion
ZPA - Zero Period Acceleration:	The acceleration level of the high frequency, non-amplified portion of the response spectrum. This acceleration corresponds to the maximum peak acceleration of the time history used to derive the spectrum.

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To M.A. Machacek
Manager of Engineering
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PROPOSAL FOR TESTS AND ANALYSIS IN THE AID OF SEISMIC QUALIFICATION OF DARLINGTON CABLE RACEWAY

1.0 INTRODUCTION

Cable raceway system for the Darlington NGS has been previously designed and qualified in a test program conducted by the Civil Engineering and Architecture Department (CEAD). This project represents a supplementary activity to the CEAD qualification in a few selected areas, as described below.

Criteria for raceway installation at the Darlington NGS have changed over the years from very rigid beam design to conventional unbraced strut system. Methods of installing the raceway vary between units and is frequently inconsistent within a unit (depending when a raceway was installed). Paths that raceways take also vary between units. This makes inspection and qualification of the existing raceway difficult and laborious.

Recent inspections revealed that many nuts made by Canstrut and used in assembling the raceway were not installed properly /1/. Preliminary examination showed that the quality of the nuts decreased so much with time that many of them could not be installed properly. Even properly installed nuts could not support the forces postulated for the DBE in the original CEAD test program.

Concessions made to the nut supplier resulted in the continual degradation of the nut quality. Figure 1 shows several different nut layouts used in the station. The main problems encountered in nut installation were:

- nuts having shapes in Figures 1c and 1d could not rotate properly, as illustrated in Figure 2.
- nuts with burrs left from forming could not rotate properly
- undersized nuts did not grip properly inside the struts (see Figure 3).
- reduced size of the gripping teeth caused by the wear out of the die.

The cost of inspecting all nuts and replacing the defective ones would be high. In this report, a less costly method for qualification of class 1 and 2 raceways is proposed.

The qualification process is further complicated by wide range of bracket qualities. Brackets at the construction site, range from 4.13 cm (1-5/8") wide hot formed to brittle 3.81 cm (1½") wide cold formed on an impact hammer. Struts used in assembly of the raceway also have a wide range of mechanical properties. Strut material thicknesses used at the station range from 1.6 mm (16 gauge) to 2.6 mm (12 gauge). In the proposed test program, an effort will be made to use all components of the lowest quality available, unless otherwise specified.

2.0 PAST TEST PROGRAM

2.1 Alternate Designs

Three basic alternative designs were used in building the Darlington cable raceway. The oldest design consisted of welded structural beams (beam design). This design offers high strength and stiffness. This style of raceway was qualified by the CEAD and will not be considered here.

A strut system having a welded top bracket and reinforced by significant bracing is the second oldest design system (braced design). An extensive test program conducted by Bechtel Power Corporation showed that this system is adequate. The top bracket is welded to the structure and bolted to the strut using through (not grip) bolts. This design should be adequate and will not be considered in this report.

The last (conventional) design is used mostly in units three and four, but is also found in other units. In this design, gusseted and L-shaped brackets (see Figure 4) mount the trapezes to the building structure. Usually the trapezes were mounted to the structure by welding a short horizontal strut to a structural beam (see Figure 5). Occasionally, a horizontal strut was welded between beams and a trapeze was hung from the strut (see Figure 6). This design has no bracing and is flexible. It was qualified by a test program (performed on site) using high quality components. Raceways built to this design contain most of the inferior and misinstalled nuts that are subject of this investigation.

2.2 Program Assumptions

A test program was conducted jointly by Civil Department and by Darlington Construction to show the adequacy of the unbraced strut design /2/. The tests concluded without any failures. This allowed for the flexible (conventional) design to be used. Several significant assumptions made in the test program are discussed here.

The first natural frequency of the raceway was estimated to be between 0.35 and 0.50 Hz. At that low frequency the raceway would not deform with the building structure during an earthquake. Building deformations under the postulated DBE is up to 75 mm. This is equivalent to the deformation of the raceway by 75 mm about the ceiling where the raceway is mounted. Based on the low natural frequency, the fatigue tests were conducted at a 150 mm displacement peak-to-peak for 50 cycles (equivalent to the 30-second duration of an earthquake).

In the test program, trapezes of the raceway were attached to a horizontal strut mounted between two beams. A significant part of the rotation at the connection between a trapeze's vertical strut and the horizontal strut was taken by the horizontal strut (a supplementary strut mounted between

two beams). This case forms an unconservative arrangement compared to the case where the vertical strut is attached to a structural beam. Deformation in a strut attached to a structural beam is absorbed only by the brackets, bolts and nuts.

3.0 PRELIMINARY OHRD TEST PROGRAM

3.1 Laboratory Tests

In June, 1990, a test program was conducted at OHRD to qualify the misinstalled nuts /3/. The program was terminated because the nuts did not hold properly and the struts slipped. In this program, the vertical strut of a trapeze was mounted "rigidly" to a frame simulating a structural beam. A static tensile load was applied to the strut. A 100% tensile load was considered to be equivalent to a seven tier raceway loaded to 102 kg/m per tier. The end of a 1 m long strut was deformed by 152 mm peak-to-peak for 50 cycles or until the strut slipped out by more than 20 mm. The nuts were torqued to 60 Nm. After only a few cycles, this torque relaxed to a fraction of the original torque. In several cases it dropped to zero.

The first test was run in three stages (see test HC-1 in Appendix A). The first stage had 25% load. Then the load increased to 50% and finally to 100% load. All bolts were retorqued between load increases. Fifty cycles were completed for all three stages of the test. However, excessive slippage of the strut resulted at 100% load. This test was not conservative because the galvanization of the nuts was damaged in the first 25% stage. During the following stages, the clamping from retorquing the nuts was between steel surfaces with the galvanization already scraped off.

Three tests (see test sheets in Appendix A) were run at 50% load. One test (HC-2) was completed successfully. In the other two tests (HC-3 and HC-4), the strut slipped out from between the brackets after only about 25 cycles.

In two additional demonstration tests, Unistrut manufactured nuts were used for comparison. The Unistrut nuts held well under 100% load even when the bolt torque dropped off. In these tests, only two Unistrut nuts (with two nuts missing) supported 100% load. Records from the demonstration tests are not available. However, the test was witnessed by several people involved in the program that attended the 21 August, 1990 meeting (see Appendix B).

3.2 In-Situ Testing

The hammer impact method was used at several locations at the station to determine the range of natural frequencies for the raceway. The three cantilevered raceways tested had natural frequencies above 12 Hz. From the response spectra, the cantilevered raceways can see accelerations of up to 0.3 g. The first natural frequencies of a trapeze mounted raceway were measured to be from about 2.5 Hz to above 10 Hz, as shown in Table I. Impact hammer tests cannot detect frequencies below 2 Hz. Some lower frequencies could have been missed in runs having the first measured frequencies below 5 Hz. The frequencies measured during the tests were at local and low input accelerations of up to 0.1 g. At the postulated DBE accelerations, the first natural frequencies could be lower by up to 20%, as described in Subsection 5.4.

4.0 PROGRAM OBJECTIVES

The cable raceway as currently installed cannot be justified to the licensing authorities as being seismically qualified. The purpose of this project, is to:

- establish the most effective method (from both technical and cost points of view) to qualify the existing layouts and hardware with the least rework
- qualify raceways with existing misaligned nuts with the least rework and without disruption to the station operation
- recommend improvements to satisfy licensing and safety requirements of the National Standard of Canada CAN3-N289.3.

5.0 REQUALIFICATION METHOD

5.1 Raceway Inspection

During September, 1990, Messrs D.A. Black, J.W. Forest and B. Teper reviewed the cable raceway installation at the station. The main observations from the visit are described below.

The raceway as installed throughout the station seems more rigid than originally assumed. The first natural frequency of many raceway runs appears to be above 6 Hz. Many runs with lower frequencies can be easily reinforced by bracing to increase their frequencies above 6 Hz, under the earthquake conditions.

Several runs were found where trapezes were mounted from the floor. Floor support may be unstable if the base joint does not have an adequate strength. If a tray moves away from its equilibrium position it is not likely to return and the deformation may continue to collapse. To prevent this, it is recommended that all floor mounted raceways be braced.

Some trapezes have improperly installed brackets. The design calls for a vertical strut to bo mounted at the top with two brackets, one gusseted and one L-shaped. The longer side of the brackets should be along the vertical strut. If the vertical struts of a trapeze are supported by two gusseted or two L-Shaped brackets, one bracket should be replaced. Alternatively, these connection types could be requalified by testing. In our test program, L-Shaped brackets were installed with the long side along a trapeze. In the plant, the long arm of the bracket was installed either along the trapeze or at the ceiling. Both bracket orientations should be evaluated in the future test program.

Brackets used for installation of cantilevered raceways have small welds between struts and mounting plates. Under a fully loaded cable tray, stresses in the weld during a DBE could exceed yield (250 MPa). A test program is proposed below to determine if the brackets are adequate.

Future raceway inspections should include examination of cable pan connectors, used for joining sections of cable trays together. This would ensure that connectors are not missing and that they are properly installed.

5.2 Revised Qualification Procedure

The procedure used for the original seismic qualification was based on conservatively low natural frequencies. The procedure proposed here will utilize actual natural frequencies as measured at the station.

Where possible, the raceway will be reinforced by bracing to increase natural frequencies in longitudinal and transverse directions. Where additional reinforcement is not possible, Canstrut made nuts may be replaced with Unistrut made nuts. Alternatively, welded bracket type H3000 could be used with non-friction (through) bolts. This change will allow for larger raceway movement. If a raceway run cannot be retrofitted, it may be qualified by analysis. To aid in the analytical qualification, the damping factor will be measured where possible. Alternatively, damping will be assumed based on the Bechtel test program /4/, described in Subsection 5.3 below.

Where large movements are allowed, an adequate space should be available to prevent interference between cable raceway and other equipment. The largest movement should be taken as 75 mm lateral displacement per meter of trapeze length.

5.3 Damping Factors

The severity of the response to the postulated earthquake depends largely on the damping ratio in the cable raceway. Much information is available on damping in a bolted cable raceway. The National Standard of Canada recommends a value of 5% for the damping ratio. An extensive test program on the bolted cable raceway was conducted by the Bechtel Power Corporation /4/. They recommend damping ratio values depend on the floor acceleration input (ZPA) and on the amount of bracing used in raceway construction. Bechtel recommended damping ratios range from 1% to 30% as described in an Ontario Hydro report /5/ (see Figures 7).

The input (ZPA) accelerations expected at the Darlington station are low (below 0.25 g). The corresponding damping factor is about 5%.

5.4 Natural Frequencies

Natural frequencies of different arrangements of cable raceways will be tested at the station. The instrumented hammer impact test was selected for testing natural frequencies and damping coefficients of the raceway. Impact tests are conducted at lower energy levels than the postulated earthquake is likely to introduce giving artificially high natural frequency results. Figure 8 shows Bechtel results relating change in natural frequencies with the input acceleration levels. From the Bechtel test results, it appears that the actual frequency (at high acceleration) could be as much as 20% below the measured frequency.

The instrumented hammer tests cannot detect frequencies below 2 Hz. The cable raceway is a continuous system with many natural frequencies. If a raceway run has its first natural frequency below 2 Hz, it should have other (higher order) frequencies between 2 and 5 Hz. If the first natural frequency is above 5 Hz, it is unlikely that any frequencies exist between 0 and 2 Hz. Besides natural frequencies, the impact method will give us the mode shapes associated with the frequencies. If a low frequency has been missed in a test, it should be evident from examination of mode shapes.

If the impact method is found not to be adequate, other approaches can be used. We are already considering tests using a hydraulic actuator mounted to a rigid wall. This method, although more expensive, will allow us to check for lower frequencies at a few selected locations.

5.5 Raceway Displacement

At present, we only have a single set of response spectra (giving response in three orthogonal directions) for the 111.0 m elevation in the Reactor Building of the Darlington station (see Figure 9). Based on these response spectra, the largest deformations of a raceway relative to the raceway's mounting location is calculated and shown in Table II. This deformation is below 1.5 cm for a raceway having first natural frequency above 3 Hz and 5% damping (4 Hz measured in impact tests).

5.6 Response Spectra

Response spectra vary between buildings and between floors in a building of the Darlington station. Response spectra should be reviewed to determine the amount of deformation that a raceway may see in all locations during a DBE event. Modification of a raceway may depend on the largest deformation a raceway can see. The review is needed to reduce the in-situ modification requirements of cable raceway. However, similar spectra should be grouped and an enveloping spectrum should be used to reduce the amount of engineering work involved. Not more than five different sets of spectra should be considered in this study.

6.0 TEST PROGRAM

The test program proposed here will consist of nine separate stages. A separate procedure will be prepared for each stage. A quality assurance program will form an integral part of each procedure. All stages are described below. Their duration and costs are estimated in Table III. The program will take about 6 months to complete and will cost about $145,000.

6.1 In-Situ Tests

The main objective of the in-situ test is to show that majority of the cable raceway runs have high first natural frequency to allow for reduced raceway motion during laboratory tests. Runs with lower frequencies will be identified for reinforcement. Results of the tests will include the measurement of a few lowest natural frequencies, corresponding mode shapes and damping ratios. The following properties of the raceway should also be recorded: trapeze length, number of tiers, approximate cable load on each tier, raceway run number and location, strut thickness, and type and orientation of the top brackets.

All raceways at the station will be placed in 16 groups according to their trapeze lengths and total cable weight (see Table IV) to limit the amount of testing required. In most cases only one representative raceway from each group will be tested for its natural frequencies, mode shapes and damping. The largest estimated raceway deformation will be determined based on the raceway's first natural frequency and location in the station. Reinforcement of a raceway will be proposed so that its deformation will not exceed an acceptable amount as determined in the test program for the nuts and brackets (see Subsections 6.3 and 6.6).

The lowest natural frequency that might be considered acceptable is 3 Hz. At this frequency, raceway displacements would be limited to below 1.5 cm from its neutral position. However, a separate test program is required to establish if this deformation is acceptable. The 8.5 Hz frequency is preferred as the cut-off point because the floor acceleration is low (below 0.5 g) for equipment having 5% damping, (see Figure 9). Displacement of such raceway would be around 0.3 cm.

6.2 Slip and Pull-Out Tests

The slip and pull-out tests are required by the Ontario Hydro manufacturing specification for the nuts /6/. According to the specification, the nuts are not acceptable if a single nut connection slips at loads below 21,000 N or the bolt pulls-out below 27,000 N for a strut made of 12 gauge steel. For 16 gauge strut the forces are 13,500 N for both load orientations. For a five tier raceway loaded to 102 kg/m per tier, this static force should be:

$$W = (3*q*n*l)/(N*a) = 9{,}500 \text{ N}$$

where	3	safety factor used in equivalent static load simulating DBE load
	q=1,000 N/m	weight of cable in a single fully loaded tier
	n=5	largest allowed number of tiers
	l=2.44 m	distance between trapezes
	N=2	number of vertical struts supporting a span
	a=2	number of top brackets mounting a strut

for the pull-out test and 4,750 N for the slip test. The proposed configurations for the two tests are shown in Figure 10. The tests will be done using all Canstrut made components as supplied for use at the station. Three different Canstrut nuts will be used in tests. Struts used in tests should be common to the station. It might be necessary to repeat some tests with different strut thicknesses. A second set of tests will be conducted using all Unistrut components, for comparison.

6.3 Tests with Properly Installed Nuts

The ability of low quality, properly installed nuts to support a raceway system will be tested. The nuts will be torqued to 68 Nm (50 ft-lbs) and relaxed by more than 8 Nm to reduce the residual torque.

New loading conditions will be used in the seismic tests. The loads used in tests have been agreed upon between Mechanical Research and CEA Departments. The number of cycles used in tests will depend on raceway first natural frequency and displacement, as shown in Figure 11 /2/. Displacements at a free end of a 1 m long strut can be obtained from Table II. A full tensile load on a trapeze will be 6,100 N (1,370 lbs). This is equivalent to a five tier raceway loaded to 102 kg/m per tier. Canstrut made 16 gauge strut should be used in these tests.

In this program, it will be shown that two Unistrut nuts are adequate for supporting a 100% loaded strut, even if 16 gauge strut is used. The nuts will be positioned at the lower holes of the two brackets along the strut.

To better understand the variation in nut strength, each load case will be repeated not less than five times for each loading condition. If a large standard deviation results from a test, up to 15 tests may be required.

6.4 Tests of Misinstalled Nuts

Nuts were found to be misinstalled at the station because they were not fully rotated (see Figure 2) or they did not grip on a strut properly (see Figure 3). Both cases will be simulated in the laboratory tests to establish the largest load that the misinstalled nuts can support. Both rigid mounting and mounting with horizontal (supplementary) strut will be used. The revised deformations and number of cycles (as described in 6.3) will be used to simulate the effect of a DBE. The tensile force will be limited to the largest force justified in tests for properly installed nuts. Each load case will be tested at least five times, as described above.

Misinstalled nuts may also be found at the brackets supporting horizontal struts on which cable trays rest. An adequate strength of these nuts must also be considered. These nuts support only a single raceway weighting up to 102 kg/m.

6.5 Effect of Brackets on Trapeze Performance

Brackets were installed at the station using different configurations (Section 4.0). The intended configuration has one gusseted and one L-Shaped brackets installed with the long sides of the brackets at the vertical strut.

Two gusseted brackets offer more stiffness than a standard configuration. Earthquake loading may result in damage to this stiff connection. Two L-Shaped brackets will offer low stiffness and may introduce a localized lower first natural frequency. Placing the brackets with their short arm at the strut may reduce stiffness of the connection and reduce the allowed slippage of the strut (until the nut slips out). These problems should be corrected or addressed in a test program.

6.6 Brittle Brackets

A number of brackets in the station have been found to be brittle. Brittle brackets can break if subjected to cyclic deformation which could be induced by an earthquake. To prevent such failures, deformations of the brackets should be limited to an acceptable level. The largest acceptable deformation should be determined in a test program. Bracket deformation in a raceway can be restricted by bracing. Bracing installed at the station should be such that deformations in both nuts and brackets are acceptably low.

Dr. G. Bellamy investigated the brittle brackets /8/. In his opinion, the brackets cannot deform plastically. This would limit the deformation of a 1 m long strut to under 0.16 cm. If this limit is not acceptable, further testing of the brackets may be required.

6.7 Cantilevered Bracket Test Program

The weld between a strut and a mounting plate of the cantilevered bracket may be inadequate to support an unbraced fully loaded tray subjected to the DBE. Several brackets should be tested in a static bending test (see Figure 12) to determine the largest load the brackets can safely support.

The acceptable combined static and dynamic load should not cause the stress in the weld to exceed yield. The combined load depends on the first vertical natural frequency and it could reach 12,200 N (2,740 lbs) at frequencies below 18 Hz.

7.0 TREATMENT OF UNITS UNDER CONSTRUCTION

Units 3 and 4 of the Darlington NGS are still under construction. Most cable trays in these units have already been installed. However, some cables have not been pulled through yet. Measuring of natural frequencies in these areas may not be useful until all cables are installed. In these cases, a visual inspection may be adequate to identify runs that might need reinforcement to ensure that the raceways have an adequately high first natural frequency. Visual inspection may be adequate based on the study of the individual groups (in Table IV) and on the experience gained in the other units. A second inspection should be conducted after cable installation is completed but before a unit is transferred to Operations.

8.0 BRACING REQUIREMENTS

8.1 Trapeze System

Raceways having their first natural frequency below the acceptable level should be braced longitudinally and transversally. Long class 2 raceways that can have large deflections should be braced also. Bracing to a structurally reinforced wall or a structural column is preferred. A brace at 45° to a ceiling is acceptable for both directions. Longitudinal bracing can be internal between trapezes (see Figure 13). The frequency of transverse bracing may range from every trapeze to every fifth trapeze depending on trapeze length, number of tiers, loading and possibly location in the station. Longitudinally, every fifth or tenth trapeze should be braced.

From this project, a table will likely be prepared with recommended bracing arrangements. It may be similar to the table prepared for Bruce B (see Table V).

8.2 Floor Mounted Trapezes

The floor mounted trapezes could be unstable. They should be made rigid (ie. have the first natural frequency above 20 Hz). This could be achieved by proper bracing to an adjacent wall. If a wall is not near, a 45° brace to the floor should be installed.

8.3 Class 1 and 2 Interaction

In a few locations, Class 2 and Class 1 raceways intersect. In these areas, Class 1 runs should be reinforced to the requirements of Class 2 for not less than three trapezes on each side of the area of intersection.

8.4 Channel A and B Separation

Channel A and B runs should be separated so that collapse of one system does not affect the other system. This separation was not preserved in all areas. Proper structural reinforcement should be considered for the areas where collapse of one system could damage the other.

9.0 NUT REPLACEMENT PROGRAM

For raceways with a low first natural frequency, it may be more economical to replace low quality nuts with Unistrut nuts. In these cases, only the lower two nuts on each vertical trapeze need to be replaced (providing this arrangement is qualified by the test program, see Section 5.3).

It is estimated that up to 6% of the Canstrut nuts are misinstalled (see Appendix B). This is a small number and it may be acceptable under certain conditions. If fewer than four nuts are adequate to support a raceway, a statistical analysis can be conducted to determine the probability of having fewer properly installed nuts than the required number. If such a probability is above an acceptable level (eg. 99.5%), the raceway may be considered acceptable. Furthermore, some strength from the misinstalled nuts can be included in the overall connection strength, as determined in the tests in 6.4.

10.0 ADVANCE QUALIFICATION PROCEDURE

Bracing or nut replacement may not be viable for some runs due to difficult access or other problems. It may be possible to qualify these runs by analysis. If geometry and cable loads on a raceway are known, loads and deformations in the vertical struts can be calculated. Floor specific response spectra will be used with measured or estimated damping. The calculated loads and deformations can be compared with the experimentally determined acceptable loads and deformations. The analytical procedure is most suitable for runs such as extra long trapezes. The procedure proposed here is similar to that used on Bruce 'B' /6/.

11.0 CLASS 1 RACEWAY QUALIFICATION PROCEDURE

The above described test programs and procedures apply to Class 2 raceways. These raceways are critical to the safe operation and shut-down of the station. They must operate during and following an earthquake. Class 1 raceways have less severe requirements, however, they must not collapse during or following an earthquake event.

The difference in qualification procedure between the two groups is the amount of allowed motion the raceway may tolerate. The raceways containing faulty nuts can be qualified against collapse by using bracing. The same bracing procedure should be used in the Class 1 areas to prevent their collapse. This should apply to ceiling and floor mounted trapezes and to cantilevered runs.

12.0 CONCLUSIONS

Recent examination of the cable raceway at the Darlington NGS showed that some aspects of the raceway have not been seismically qualified. A procedure is proposed to provide the required cable raceway qualification. The described qualification procedure will require about 25 weeks to complete and will cost approximately $145,000. This report presents a proposal for the qualification test program. Your comments, suggestions or clarifications are welcomed to ensure that the program addresses all cable raceway concerns. Please address your comments to B. Teper at KB-223 or call 405+6089.

13.0 ACKNOWLEDGMENTS

The proposed program was a result of discussions and meetings between the Research Division, Darlington Engineering, Darlington Construction and Civil Engineering and Architecture Departments. The authors acknowledge and thank all involved for their contributions. Funding for the project is provided by the Darlington Construction Department.

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REFERENCES

1. Memorandum from C.J. Royce to J.D. Tulk dated January 9, 1990, (file NK38-57400-P)

2. P.K.L. Ko, "Darlington GS A Seismic Qualification of Group I Unbraced Cable Support System", Design and Development Division report number 973/NK38-57400 - 86190, dated July, 1986.

3. J.D. Tulk, D.A. Black, Ontario Hydro Research Division Test Procedure 89-21-001, dated June 25, 1990.

4. Bechtel Power Corporation Project, "Cable Tray and Conduit Raceway Seismic Test Program", ANCO Report Number 1053-21.1- 4, Dated 1978.

5. B. Teper, "Basis for the Seismic Qualification of the Cable Raceway System for Bruce NGS 'B' - Part 5 -Qualification by Analysis", Ontario Hydro Research Division Report Number 83-399-CON, Dated July 3, 1984

6. B. Teper, "Basis for the Seismic Qualification of the Cable Raceway System for Bruce NGS 'B' - Part 1 -Summary", Ontario Hydro Research Division Report Number 83-395-CON, Dated February 16, 1984.

7. Ontario Hydro Standard Specification Number M-512-83, Strut Material, Issued July, 1983.

8. G. Bellamy, "Brittle Fracture of Cable Tray Components, Darlington NGS", Ontario Hydro Research Division Report Number M90-i-H, Dated January 19. 1990.

TABLE I

MEASURED NATURAL FREQUENCIES

Test Number	Type of Raceway	Length of Trapezes (Meters)	Number of Tiers	Average Loading (%)	Transverse Frequency (Hz)	Longitudinal Frequency (Hz)	Friction Ratio (%)
1	Cantilever	-	-	100	18.2	12.6	2.0
2	Cantilever	-	-	100	•50	-	•
3	Trapeze	•	4	40	13.9	8.0	0.9
4	Trapeze	1.63	5	50	7.2	7.3	0.3
5	Trapeze	1.60	4	100	6.8	7.4	1.1
6	Trapeze	5.18	4	70	3.7	3.7	1.3
7	Trapeze	5.18	7	45	3.7	3.0	1.7
8	Trapeze ♦	5.08	10	40	3.0	2.4	1.7
9	Trapeze	1.45	2	50	10.0	14.5	0.6

NOTES:

1. For the cantilevered runs, vertical frequencies are listed in the transverse column
2. Where the first natural frequency is below 5 Hz, lower frequencies may be present but were not detected.
3. Listed natural frequencies could be up to 20% higher than frequencies during a DBE.
4. Average loading is calculated as the total load in all tiers divided by number of tiers.
5. • raceway has a double width.
6. • friction ratio could not be measured but it is high, above 20%.
7. ♦ four-inch-square structural beams are used for vertical components of trapezes.

TABLE II

DISPLACEMENT OF A CABLE RACEWAY

Damping Ratio (%)	Displacement (cm) at a Frequency (Hz)						
	0.5	1.0	3.0	4.0	6.0	8.0	10.0
1.0	8.4	8.1	1.8	3.8	1.5	0.6	0.15
2.0	8.4	6.4	1.6	1.9	0.8	0.5	0.14
3.0	8.4	5.7	1.4	1.7	0.8	0.4	0.13
5.0	8.4	4.6	1.3	1.4	0.7	0.3	0.12
10.	8.4	3.6	1.1	1.1	0.6	0.2	0.11
15.	8.4	3.1	1.0	1.0	0.5	0.2	0.10
20.	8.4	2.8	0.9	0.9	0.5	0.2	0.10

TABLE III

SCOPE OF TESTS

Test Number	Test Description	Required Prior Tests	Estimated Completion Date	Estimated Cost ($1,000)
1	In Situ Test	None	March 15/91	33
2	Slip Test	None	January 31/91	6
3	Pull-Out Test	None	February 15/91	5
4	Nut Hardness	None	February 28/91	2
5	Properly Installed Nuts	2, 3	March 31/91	25
6	Mis-Installed Nuts	5	April 30/91	18
7	Effect of Brackets	5	May 31/91	11
8	Brittle Brackets	None	June 15/91	10
9	Cantilevered Brackets	None	April 30/91	10
10	Project Administration	All	June 30/91	25
Totals			June 30/91	145

TABLE IV

RACEWAY GROUPS

Trapeze Length (m)	Total Cable Loading on a Raceway (%) (100%=510 kg/m of Raceway Length)			
	0 TO 30	30 TO 50	50 TO 75	75 TO 100
0.5 To 1.25				
1.25 To 2.0	9	4		5
2.0 To 3.0				
Above 3.0		6	7	

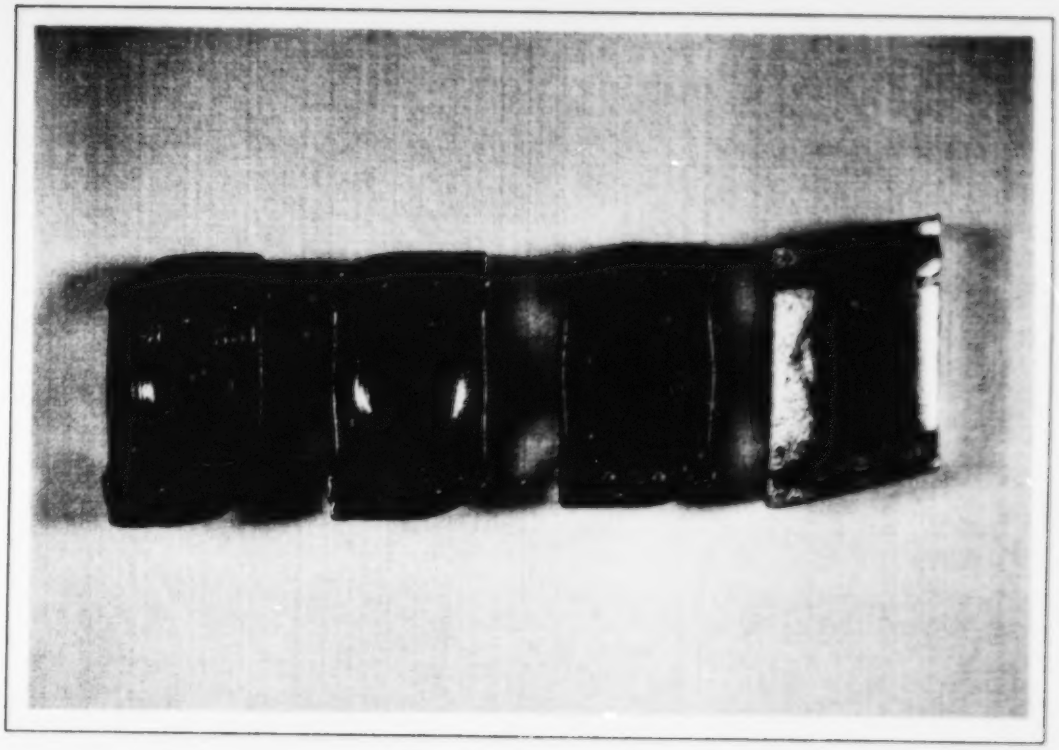
The table organizes all raceways within the station into 16 groups to be used in specifying bracing requirements. Numbers inside the table refer to the preliminary tests from Table I that represent this case and that already have been tested.

TABLE V

ILLUSTRATION OF BRACING REQUIREMENTS
(SUMMARY FOR BRACING REQUIREMENTS IS FOR BRUCE 'B' CABLE RACEWAY)

Building	Elevations or Locations	Directions of Raceway	Bracing Type	Max. Number of Tiers	Max. Length of Strut** (m)
Reactor	All Except Rooms 117, 118, 119	All	None	3	3.25
Reactor	All	T and V	T5	5	3.25
Reactor	Rooms 117, 118, 119	T and V	None	3	3.25
Reactor	Rooms 117, 118, 119	L and V	L2	3	3.25
Power House	All	All	None	3	3.25
Power House	All	T and V	T5	5	4.05
Power House	All	All	T5 & L2	6	2.44
Accumulator	All	T and V	None	3	3.25
Accumulator	All	T and V	T5	5	4.05
Accumulator	All	L and V	L2	3	3.25
Vacuum	All	T and V	T5	1	1.4
Vacuum	All	Tand V	T5	3	3.25
Vacuum	All	L and V	L2	3	3.25
Service	All	T and V	None	1	1.4
Service	All	T and V	None	3	3.25
Service	Up to 663 ft.	L and V	None	3	3.25
Service	680 ft. and Up	L and V	L1	3	3.25
Emergency Supply	All	T and V	T5	1	1.4
Emergency Supply	All	T and V	T5	3	3.25
Emergency Supply	All Except Walls	L and V	L2	3	3.25
Emergency Supply	Walls	L and V	L1	3	1.4
Emergency Supply	Walls	T and V	T5	1	1.3
Emergency Supply	Walls	T and V	T1	3	3.25

Notes: This table covers standard arrangements, not requiring analyses.
* V-vertical, T-transverse, L-longitudinal.
This is the length from mounting point to lowest tier.



a) Unistrut nut b) Original nut c) Nut with bars d) Trapezoidal nut

Various Canstrut Nuts

FIGURE 1

DIFFERENT NUT GEOMETRIES

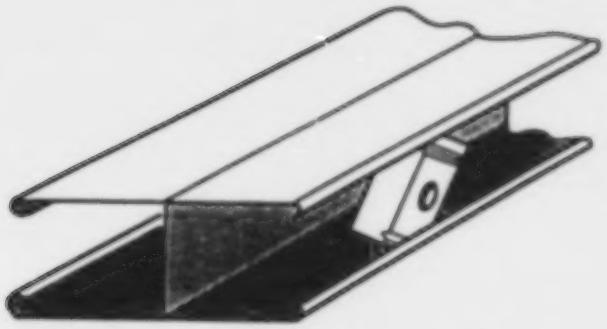


FIGURE 2

MISROTATED NUT

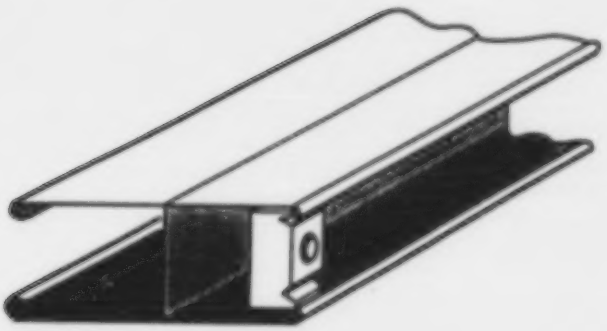
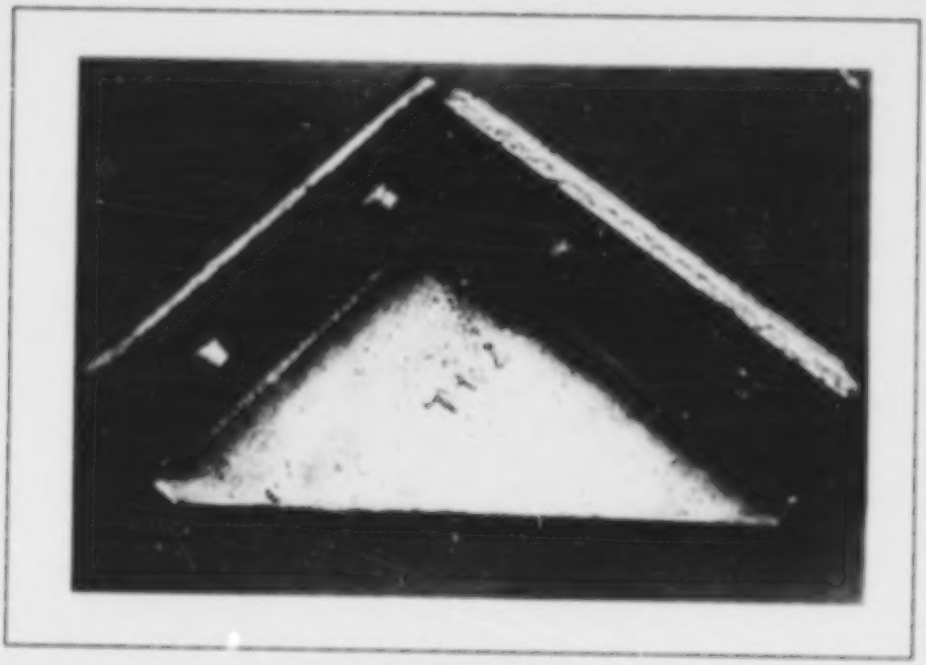
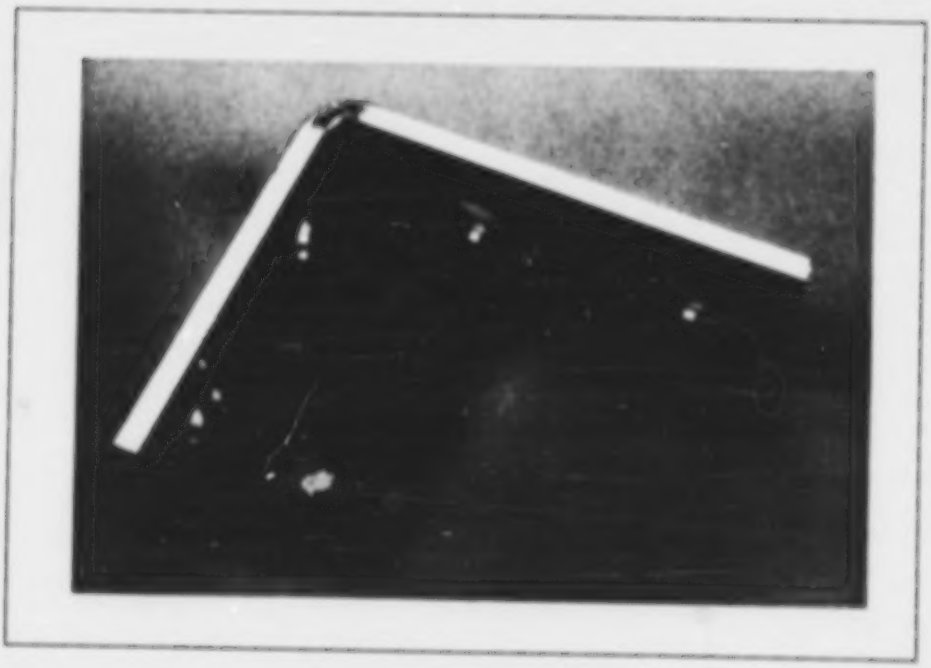


FIGURE 3

MISINSTALLED SMALL SIZE NUT



a) Gusseted Bracket



b) L-shaped Bracket

FIGURE 4

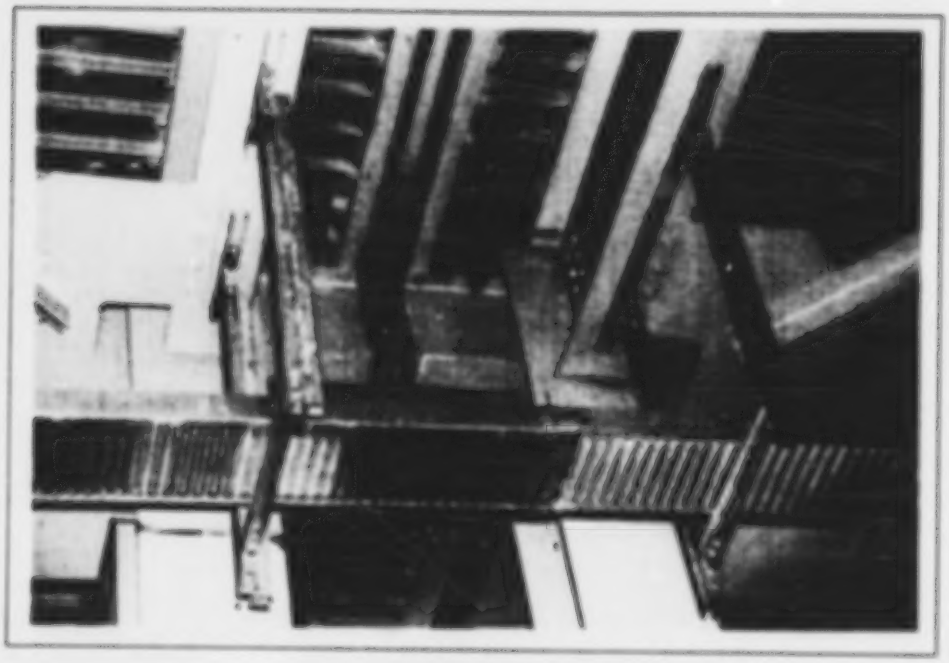


FIGURE 5

RIGID MOUNTING OF STRUTS

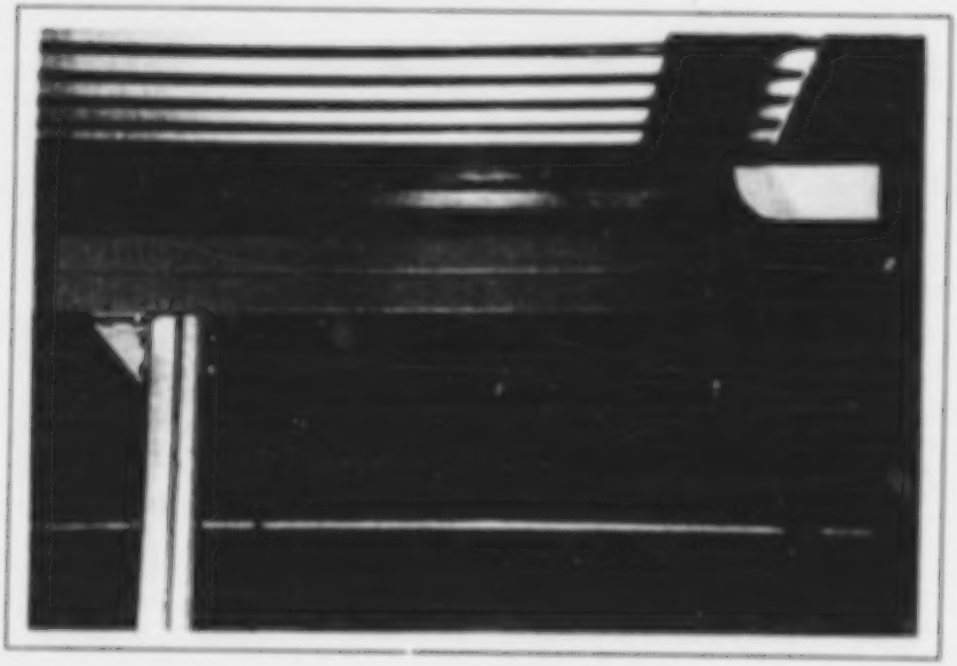


FIGURE 6

SUPPLEMENTARY STEEL ARRANGEMENT

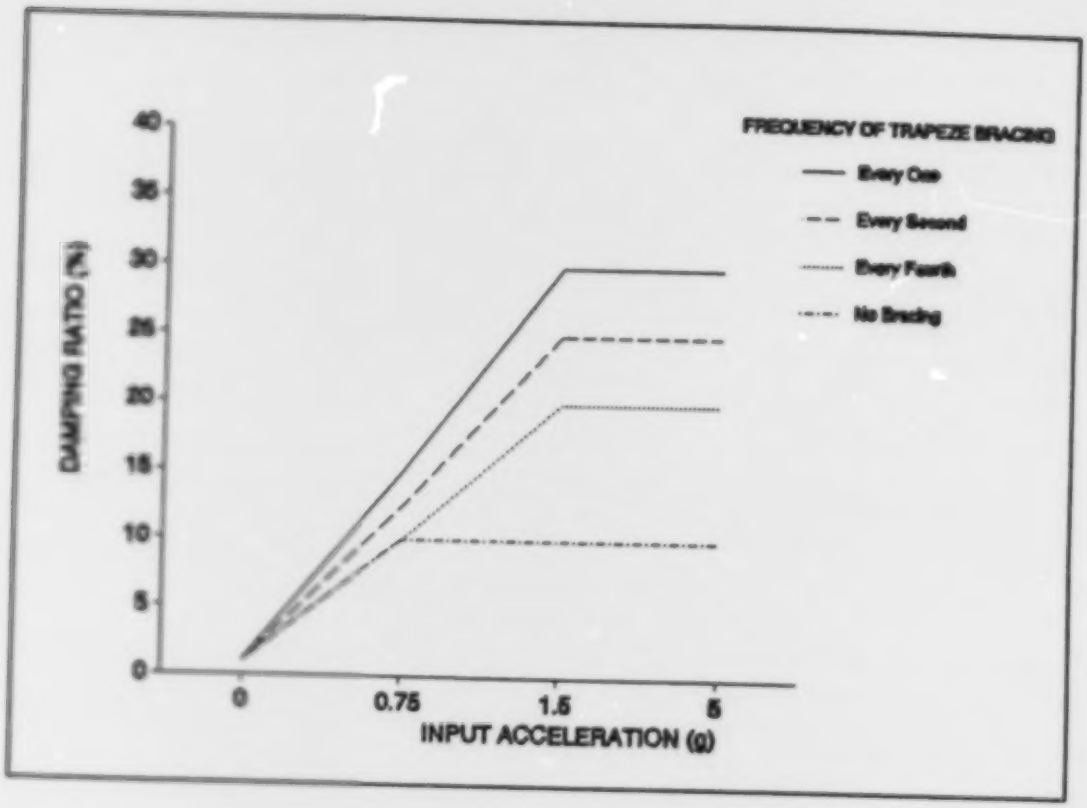


FIGURE 7

BECHTEL DERIVED DAMPING RATIO

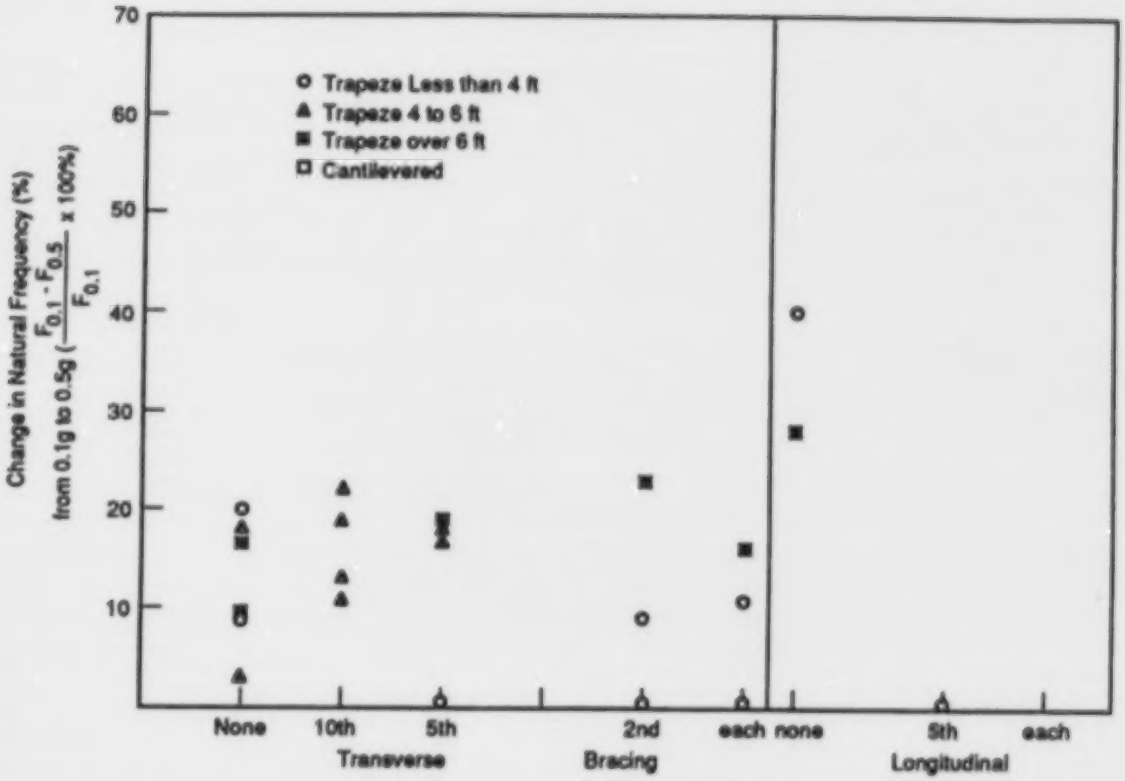
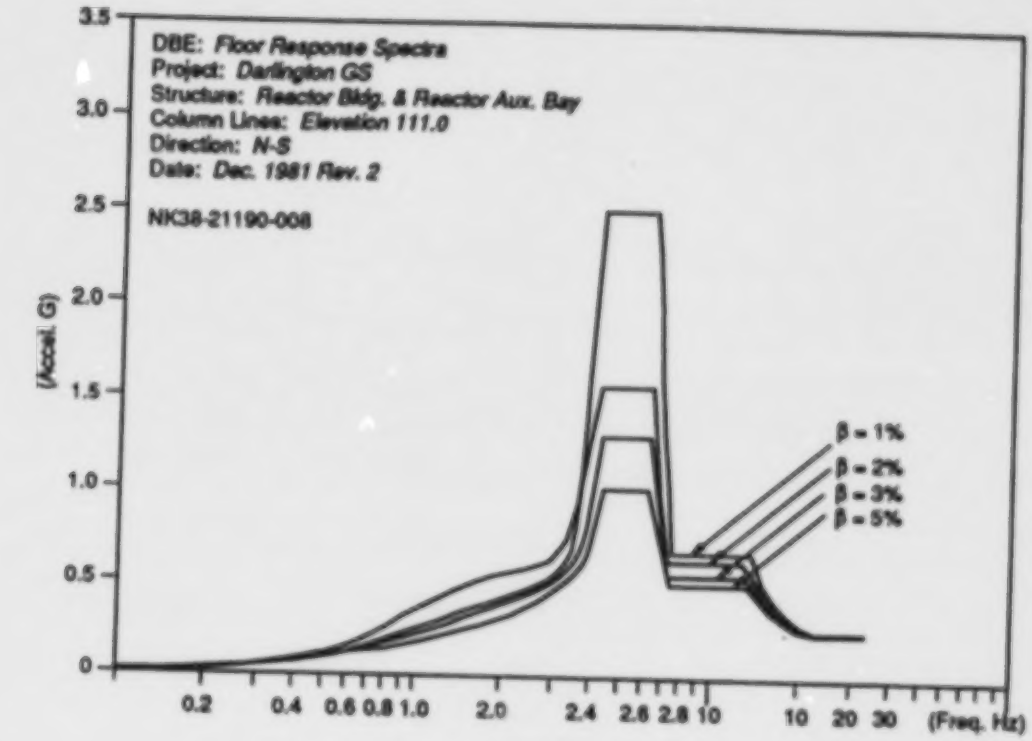


FIGURE 8

NATURAL FREQUENCY RATIOS



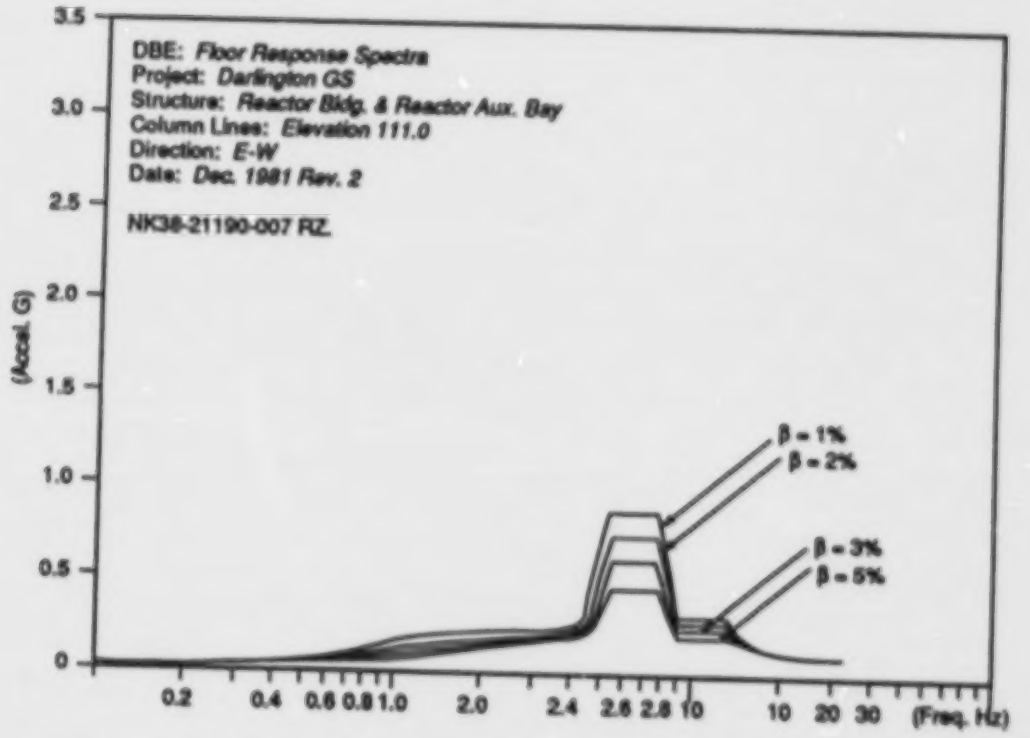
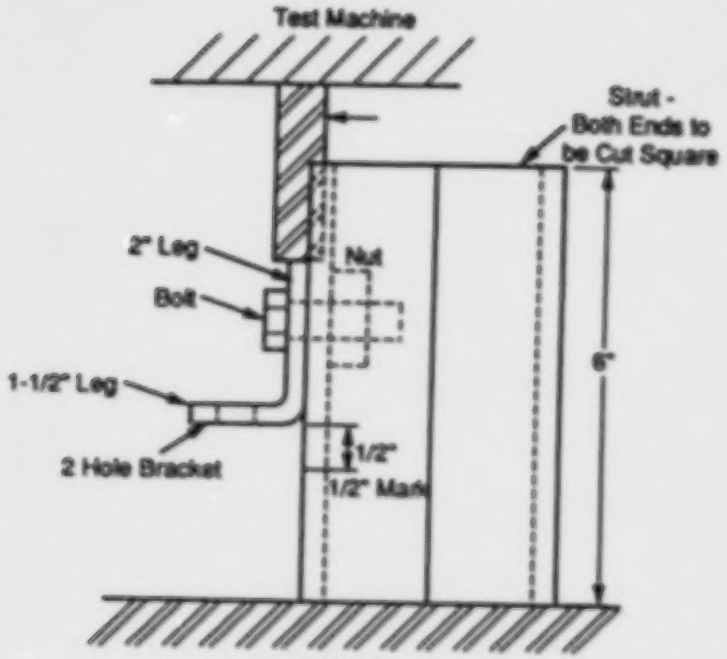


FIGURE 9

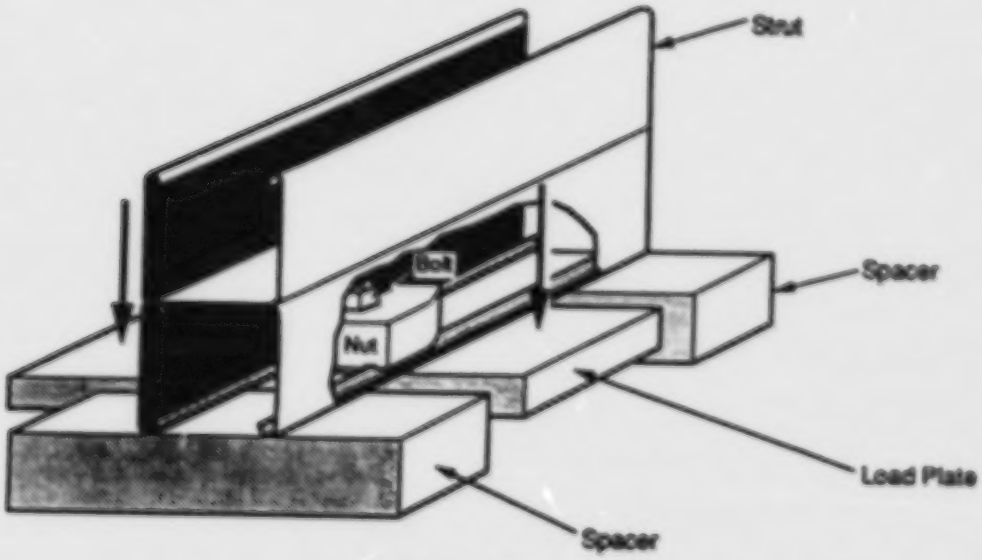
DARLINGTON FLOOR RESPONSE SPECTRA

91-48-K

184487 RD-A36



a) Slip Test



b) Pull-out Test

FIGURE 10

ARRANGEMENT USED FOR SPECIFICATION REQUIRED TESTS

91-48-K
185303-AF42-RD

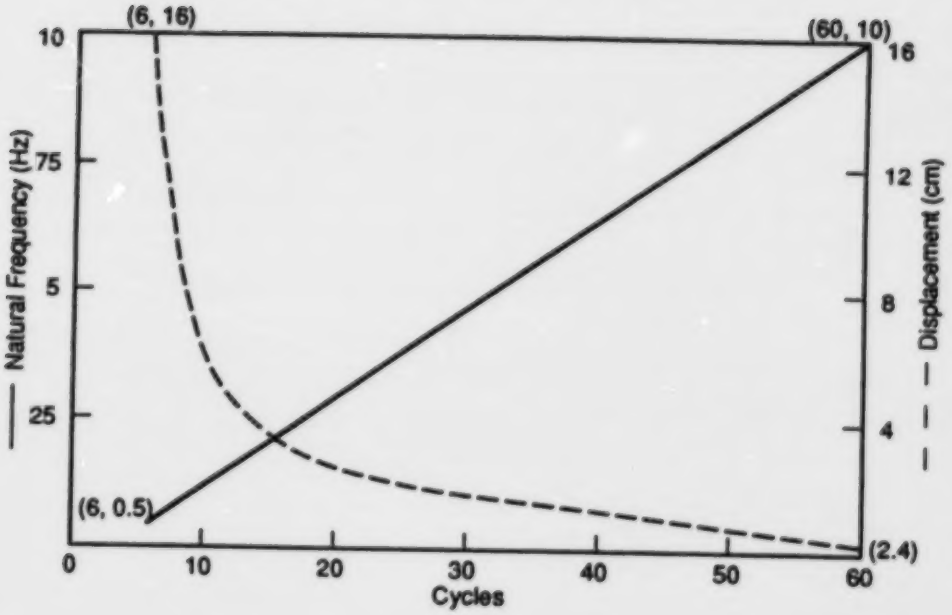


FIGURE 11

RACEWAY DISPLACEMENT

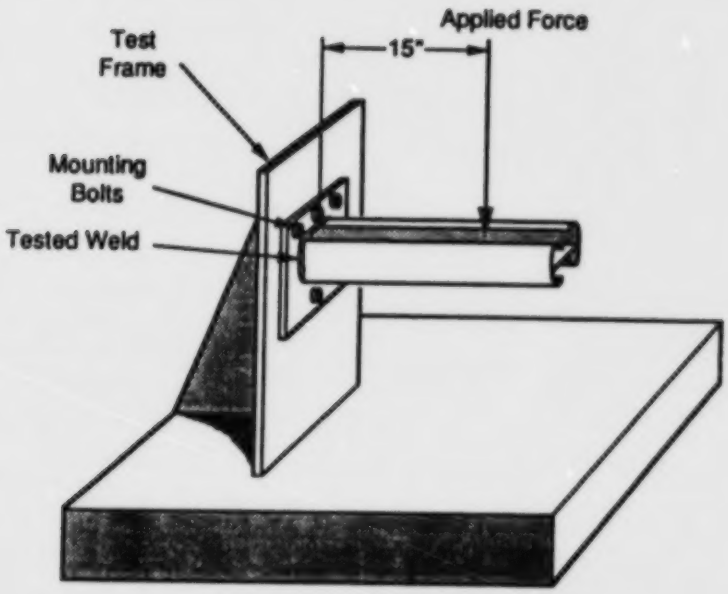
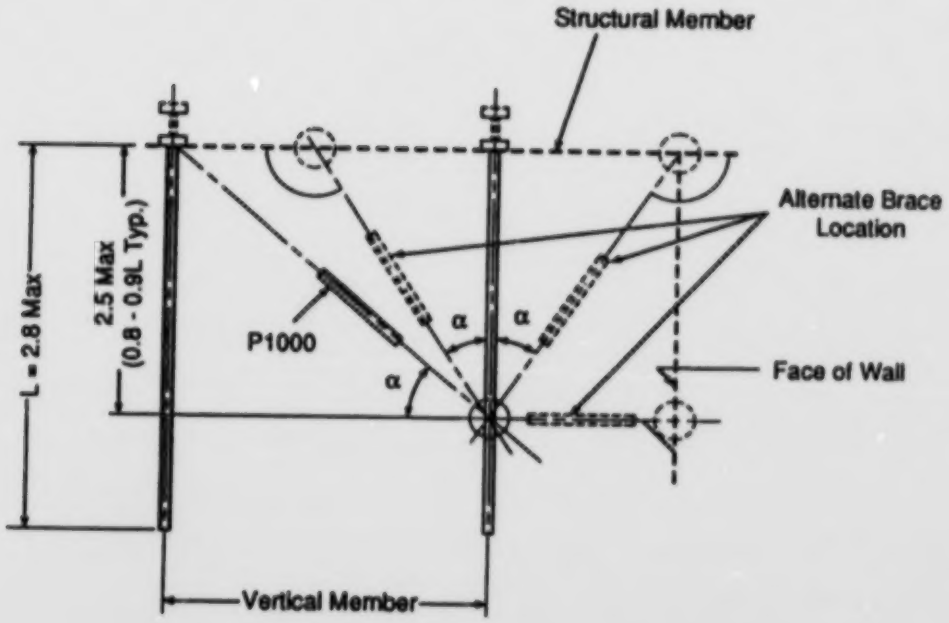


FIGURE 12

TEST ARRANGEMENT FOR CANTILEVERED BRACKET



All dimensions are in meters

FIGURE 13

LONGITUDINAL BRACING

91-48-K
184496 RD-A35

APPENDIX A

PRELIMINARY QUALIFICATION TEST RESULTS

ONTARIO HYDRO RESEARCH TEST PROCEDURE 89-21-001
REVISION: 0
JUNE 25, 1990

TEST PROCEDURE FOR SEISMIC QUALIFICATION OF CABLE TRAY SUPPORT ASSEMBLIES BUILT FROM CANADA STRUT AND UNISTRUT GTE COMPONENTS WITH SELECTED DEFECTS USED IN DARLINGTON NGS A

PREPARATION

PREPARED AND REVIEWED BY: J.D. Tulk — July 3/90 (DATE)

PREPARED AND REVIEWED BY: D.A. Black — June 29/90 (DATE)

QUALITY ASSURANCE: J. Jackson — Jan 7/90 (DATE)

APPROVAL

APPROVED BY: M.H. Thompson, Ontario Hydro Engineering — 27 July 90 (DATE)

RECEIVED JUL 25 1990
CONTROLLED 2 OF 2
PERMANENT
NON-PERMANENT X
23 pp.

1.0 SCOPE

This test procedure shall be used to qualify cable tray support assemblies built from components manufactured by Canada Strut and Unistrut GTE for service at Darlington GSA.

Cable trays at Darlington NGS A that carry safety related wiring or which pass close to critical equipment were seismically qualified by a combination of test and analysis. Qualification of Group I cable tray supports was based on tests of several "standard" hardware configurations. These configurations were subjected to loads representing a conservative combination of trays loaded to capacity and extreme seismic shaking.

During construction it was found that some sub-standard connecting hardware had been used. Two types of defects were found which resulted in misaligned nuts in the channel. In some cases the nut would not rotate into the desired position, see Figure 1. In other cases the nuts only gripped the rail on one side, see Figure 2.

The original seismic qualification tests assumed tray loadings of up to 102 kg of cable per metre. This procedure establishes qualification loads for cable tray supports with defects. These loads shall represent trays loaded to 25, 50 or 100% of the original qualification load.

The tests shall cover three common cable tray support configurations:
Group I Hanger Strut Top Support Brackets
Horizontal Tray support Assemblies
and Group II Cantilever Brackets.

2.0 SAMPLE DESCRIPTION

The following samples shall be constructed as described below.

SAMPLES HC-1, HC-2, HC-3, HC-4, (NO DEFECTS)
HR-1, HR-2, HR-3, HR-4, (NUTS PARTLY ROTATED)
HE-1, HE-2, HE-3 AND HE-4 (NUTS ENGAGED ON ONE SIDE ONLY)

Group I hanger brackets assembled as per Figure 3 and each sample consisting of the following:
A - (1 required) UNISTRUT, P-1000, DOUBLE STRUT, cut to 0.5 m.
B - (1 required) UNISTRUT, P-1000, DOUBLE STRUT, cut to 1.1 m.
C - (1 required) UNISTRUT, P2484, SEVEN HOLE GUSSETED WEB BRACKET, four bolts to be used.
D - (1 required) CANSTRUT, CS116-4, STOCK CODE 391A5262, FOUR HOLE CORNER ANGLE.
E - (8 required) 1/2 INCH, CADMIUM PLATED, GRADE 2, HEX HEAD CAP SCREWS, UNC-2A x 1-1/2 INCH, STOCK CODE 251G982A.
F - (8 required) CANSTRUT, STOCK CODE 391A5542, NUTS.

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91-48

SAMPLES TLC-1, TLC-2, TLC-3, TLC-4, (NO DEFECTS)
TLR-1, TLR-2, TLR-3, TLR-4, (NUTS PARTLY ROTATED)
TLE-1, TLE-2, TLE-3 AND TLE-4 (NUTS ENGAGED ON ONE SIDE ONLY)

Horizontal Tray support Assemblies assembled as per Figure 5 and each sample consisting of the following:
A - (1 required) UNISTRUT, P-1000, DOUBLE STRUT, cut to 0.5 m.
B - (2 required) UNISTRUT, P-1000, DOUBLE STRUT, cut to 1.1 m.
D - (2 required) CANSTRUT, CS116-4, STOCK CODE 391A5262, FOUR HOLE CORNER ANGLE.
E - (8 required) 1/2 INCH, CADMIUM PLATED, GRADE 2, HEX HEAD CAP SCREWS, UNC-2A x 1-1/2 INCH, STOCK CODE 251G982A.
F - (8 required) CANSTRUT, STOCK CODE 391A5542, NUTS.

SAMPLES TVC-1, TVC-2, TVC-3, TVC-4, (NO DEFECTS)
TVR-1, TVR-2, TVR-3, TVR-4, (NUTS PARTLY ROTATED)
TVE-1, TVE-2, TVE-3 AND TVE-4 (NUTS ENGAGED ON ONE SIDE ONLY)

Horizontal Tray support Assemblies assembled as per Figure 6 and each sample consisting of the following:
B - (2 required) UNISTRUT, P-1000, DOUBLE STRUT, cut to 1.1 m minimum.
E - (2 required) 1/2 INCH, CADMIUM PLATED, GRADE 2, HEX HEAD CAP SCREWS, UNC-2A x 1-1/2 INCH, STOCK CODE 251G982A.
F - (2 required) CANSTRUT, STOCK CODE 391A5542, NUTS.
G - (1 required) CANSTRUT, STOCK CODE 393F5952, WELDED CABLE TRAY SUPPORT BRACKET, nominally 560 mm long.

SAMPLES HSC-1, HSC-2, HSC-3, HSC-4, (NO DEFECTS)
HSR-1, HSR-2, HSR-3, HSR-4, (NUTS PARTLY ROTATED)
HSE-1, HSE-2, HSE-3 AND HSE-4 (NUTS ENGAGED ON ONE SIDE ONLY)

Group II hanger brackets assembled as per Figure 8 and each sample consisting of the following:
A - (2 required) UNISTRUT, P-1000, DOUBLE STRUT, cut to 0.5 m.
E - (8 required) 1/2 INCH, CADMIUM PLATED, GRADE 2, HEX HEAD CAP SCREWS, UNC-2A x 1-1/2 INCH, STOCK CODE 251G982A.
F - (8 required) CANSTRUT, STOCK CODE 391A5542, NUTS.
H - (2 required) CANSTRUT, STOCK CODE 391A5444, CABLE TRAY SUPPORT BRACKET, cantilever nominally 800 mm long.
I - (1 required) CABLE TRAY, SV45300CG2, nominally 3 m long.

These configurations represent installed cable tray supports at Darlington NGS. All components shall be supplied by Darlington NGS and prepared by laboratory personnel.

Preparation

Samples selected to be tagged with an xxC-x designation shall be constructed without defects.

Samples selected to be tagged with an xxR-x designation shall have the defect shown in Figure 1 at all bolts. The flanges on the strut shall be deformed such that the nuts cannot rotate beyond approximately 45 degrees.

Samples selected to be tagged with an xxE-x designation shall have the defect shown in Figure 2 at all bolts. The nut shall be properly seated on the same side of the channel. The flanges on the strut shall be deformed such that the nuts shall not engage the strut on the other side.

The samples shall assembled by laboratory personnel. All 1/2 inch bolts shall be torqued to 45 ± 5 ft-lbf.

3.0 TEST SEQUENCE

Visual Inspection
Baseline Functional Tests
Seismic Testing
Post Seismic Functional Tests

4.0 GENERAL REQUIREMENTS

All out of tolerance conditions shall be documented by Notice of Anomaly (NOA). Darlington Engineering shall be notified within 24 hours, excluding weekends and holidays, of the anomaly.

The testing shall be in accordance with Ontario Hydro, Mechanical Research Department, QA Procedures.

5.0 ACCEPTANCE CRITERIA

Test results for samples ending in -1 shall be used to establish test loads only.

Samples ending in -2, -3 and -4 shall be capable of carrying the test load without slippage in the load carrying direction greater than 20 mm.

Torque measurements shall be for information only.

If any samples do not meet the acceptance criteria testing shall continue.

6.0 DETAILED TESTS

6.1 VISUAL INSPECTION

Record the results of the detailed inspection on the test specimen inspection sheet ATTACHMENT A. Wire a tag or engrave each sample indicating the sample number. The inspection sheet numbers and tag numbers should match the sample descriptions of paragraph 2.0.

6.2 BASELINE FUNCTIONAL TEST FOR Hx-x SAMPLES

6.2.1 Samples HC-1, HR-1 and HE-1 shall be installed in the test fixture, see Figure 4. Monitoring equipment shall be connected to record the axial load and the lateral deflection. The fixture shall be reinforced to minimize fixture deformations. Photograph typical test set-ups.

6.2.2 The 1/2 inch bolts shall be tightened to 45 ± 5 ft-lbf and the gap at the base shall be measured and the results recorded on ATTACHMENT B or equivalent.

6.2.3 With an axial load of 2000 ± 200 N (representing 25% cable loading) applied, cycle the lateral displacement using a sine wave at a maximum frequency of 1 Hz to a peak to peak displacement of 150 ± 15 mm for a minimum of 50 cycles.

6.2.4 Measure the bolt torques and the gap at the base and record the results on ATTACHMENT B or equivalent.

6.2.5 If the sample holds the load then restore the sample to its original gap at the base and bolt torques. Record the results on ATTACHMENT B or equivalent. Record the load used as the Hx sample's "load limit". If the load is not held then the testing on this sample is complete.
Note: The maximum axial load achieved without excessive slippage is defined as the "load limit".

6.2.6 Repeat the functional tests of 6.2.2, 6.2.3, 6.2.4 and 6.2.5 at axial loads of 4000 ± 400 N and 7750 ± 775 N. This completes the testing on these samples.

6.2.7 For the qualification samples HC-2, HC-3, HC-4, HR-2, HR-3, HR-4, HE-2, HE-3 and HE-4, the only functional tests shall be to tighten the 1/2 inch bolts to 45 ± 5 ft-lbf.

6.3 BASELINE FUNCTIONAL TESTS FOR TLx-x SAMPLES

6.3.1 Samples TLC-1, TLR-1 and TLE-1 shall be installed in the test fixture, see Figure 7. Monitoring equipment shall be connected to record the axial displacement and the lateral deflection. The fixture shall be reinforced to minimize fixture deformations. Photograph typical test set-ups.

6.3.2 The 1/2 inch bolts shall be tightened to 45 ± 5 ft-lbf and the bracket position shall be measured and the results recorded on ATTACHMENT C or equivalent.

6.3.3 With an axial load of 1000 ± 100 N (representing 25% cable loading) applied, cycle the lateral displacement using a sine wave at a maximum frequency of 1 Hz to a peak to peak displacement of 150 ± 15 mm for a minimum of 50 cycles.

6.3.4 Measure the bolt torques and the slip and record the results on ATTACHMENT C or equivalent.

6.3.5 If the sample holds the load then restore the sample to its original gap at the base and bolt torques. Record the results on ATTACHMENT C or equivalent. Record the load used as the TLx sample's "load limit". If the load is not held then the testing on this sample is complete.
Note: The maximum axial load achieved without excessive slippage is defined as the "load limit".

6.3.6 Repeat the functional tests of 6.2.2, 6.2.3, 6.2.4 and 6.2.5 at axial loads of 2000 ± 200 N and 3700 ± 370 N. This completes the testing on these samples.

6.3.7 For the qualification samples TLC-2, TLC-3, TLC-4, TLR-2, TLR-3, TLR-4, TLE-2, TLE-3 and TLE-4, the only functional tests shall be to tighten the 1/2 inch bolts to 45 ± 5 ft-lbf.

6.4 BASELINE FUNCTIONAL TESTS FOR TVx-x SAMPLES

6.4.1 The tests for the TV samples shall be identical to the TL samples. Use ATTACHMENT D or equivalent to record the results. Record the TVx "load limits" as described above.

6.5 BASELINE FUNCTIONAL SEISMIC TESTS FOR HSx-x SAMPLES

6.5.1 Samples HSC-1, HSR-1 and HSE-1 shall be installed on the test fixture, see Figure 8. Monitoring equipment shall be connected to record the table accelerations. The fixture shall be reinforced to minimize fixture deformations. Photograph typical test set-ups.

6.5.2 The 1/2 inch bolts shall be tightened to 45 ± 5 ft-lbf and the vertical position of the brackets marked on the strut and the results recorded on ATTACHMENT E or equivalent.

6.5.3 The cable tray shall be dead weighted with a uniformly distributed total mass of 100 ± 5 kg (representing 25% cable loading). The samples shall be subjected to the Required Response Spectra (RRS) as shown in Figure 9, 10 and 11 with the horizontal directions combined into one overall worst case spectrum. No margin shall be added to the requirements. The test response spectrum shall be plotted at 5% damping. Record the tests on ATTACHMENT E or equivalent.

6.5.4 Measure the bolt torques and the slip and record the results on ATTACHMENT E or equivalent.

31
91-48

6.5.5 If the sample holds the load then restore the sample to its original gap at the base and bolt torques. Record the results on ATTACHMENT E or equivalent. Record the mass used as the MSx sample's "mass limit". If the load is not held then the testing on this sample is complete.
Note: The maximum mass loading achieved without excessive slippage is defined as the "mass limit".

6.5.6 Repeat the functional tests of 6.5.2, 6.5.3, 6.5.4 and 6.5.5 at mass loads of 200 ± 10 kg and 370 ± 17 kg. This completes the testing on these samples.

6.5.7 For the qualification samples MSC-2, MSC-3, MSC-4, MSR-2, MSR-3, MSR-4, MSE-2, MSE-3 and MSE-4, the only functional tests shall be to tighten the 1/2 inch bolts to 45 ± 5 ft-lbf.

6.6 QUALIFICATION LOAD TESTING OF Rx-x, TLx-x AND TVx-x SAMPLES

6.6.1 Each sample shall be mounted and tested at the sample's "load limit" using the set-up and procedures described in the baseline functional tests.

6.6.2 Record the test results on the appropriate ATTACHMENT. Photograph typical test set-ups.

6.7 QUALIFICATION SEISMIC TESTING OF MSx-x SAMPLES

6.7.1 Each sample shall be mounted and tested at the sample's "mass limit" using the set-up and procedures described in the baseline functional tests.

6.7.2 Record the test results on the appropriate ATTACHMENT. Photograph typical test set-ups.

6.8 POST QUALIFICATION FUNCTIONAL TESTS ALL SAMPLES

6.8.1 Record the torque and the amount of slip on the appropriate ATTACHMENT.

6.8.2 A thorough visual inspection shall be performed. Record the results of the visual inspection on the appropriate ATTACHMENT.

7.0 TEST EQUIPMENT

An Instrumentation Sheet shall be completed for all instruments used in the testing at the time of test. A sample instrumentation sheet is included as ATTACHMENT F. Separate sheets are completed for each phase of the test program. The instrumentation sheet shows the following:

Equipment name
Model number
Serial number
Accuracy
Calibration date
Calibration due date
Remarks

All equipment used shall have calibration labels and current calibration records on file in accordance with the Quality Assurance Program.

8.0 QUALIFICATION REPORT

A preliminary report and copies of the test data shall be provided within 15 days of completion of the testing. The final report shall contain the following:

Sample description
Approved test procedure
Preliminary report
All test data
Instrumentation sheets
All Notices of Anomaly

The final report shall meet the intent of the requirements for reports in IEEE 323-1975 and IEEE 344-1975.

9.0 QUALITY ASSURANCE

The test program shall be performed and all reports shall be prepared in accordance with the Quality Assurance program. This program conforms to the applicable portions of the Canadian Standards Association N286. All test equipment shall be traceable the National Research Council or equivalent.

information sheet

design notes

Project (Subject) Nuts | Nut 36 | April 12 1970

Subject: Qualification of Cold Tap Heat-treat

J D Tuft

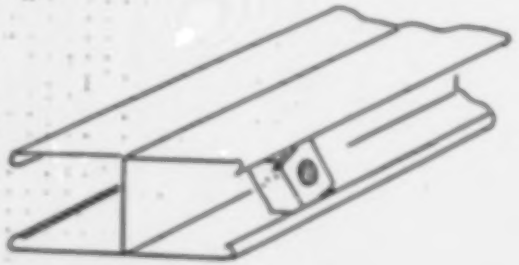


Figure 1: Nut Incompletely Rotated due to Shape Defect

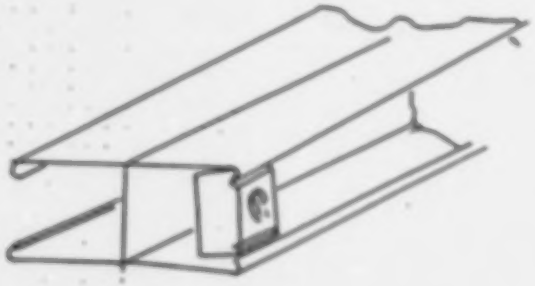


Figure 2: Nut Improperly Installed due to Spread Strut Flanges

information sheet

design notes

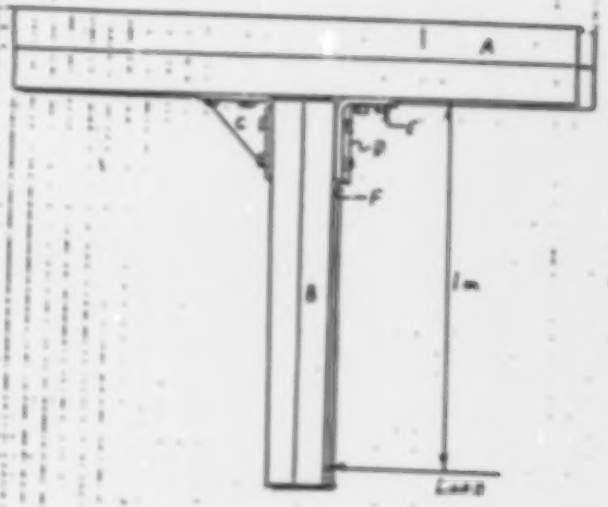


Figure 3: Standard Group I Hanger Bracket Detail SAMPLES HC-1, HE-1 & HE-2

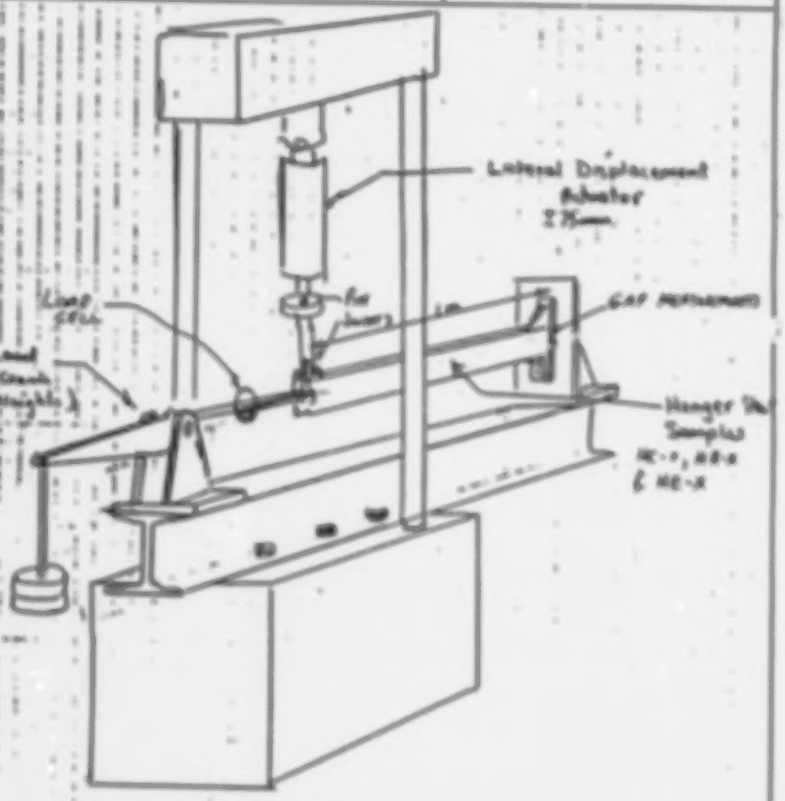


Figure 4 : Schematic of Test Setup for Group I Hanger Steel Bracket

Figure 5: Typical Group I Horizontal Tray Support Assembly SAMPLES TLC-1, TLA-1 & TLE-1

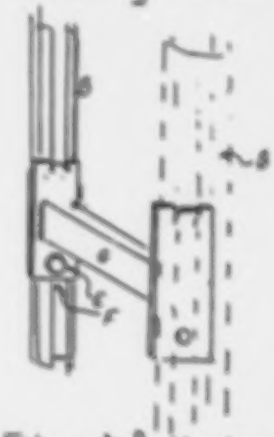
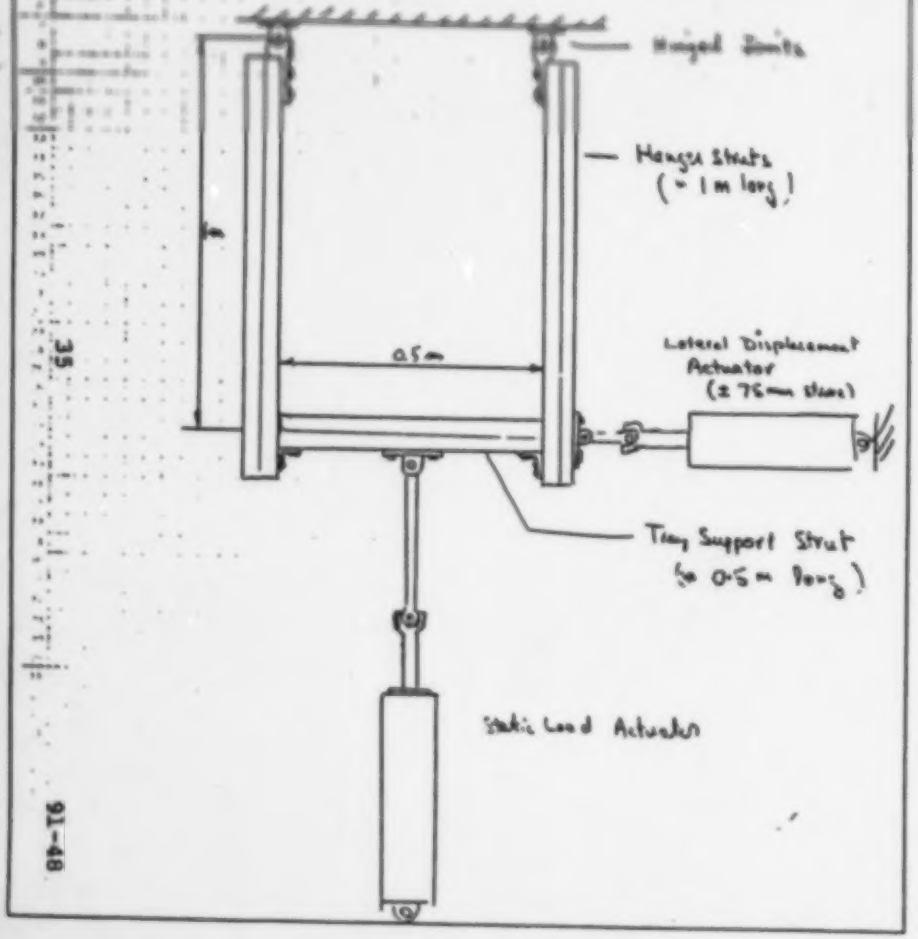


Figure 6 : Fabricated Horizontal Steel SAMPLES TWC-1, TWA-1 & TWE-1.

information sheet

Figure 7 Test Setup for Horizontal Tray Support Assemblies



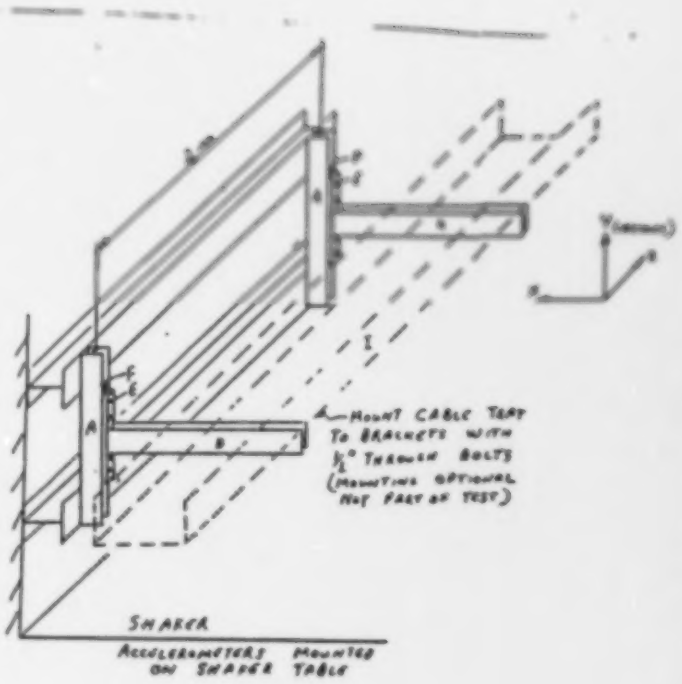

A — MOUNT CABLE TRAY TO BRACKETS WITH ½" THROUGH BOLTS (MOUNTING OPTIONAL NOT PART OF TEST)
SHAKER
ACCELEROMETERS MOUNTED ON SHAKER TABLE

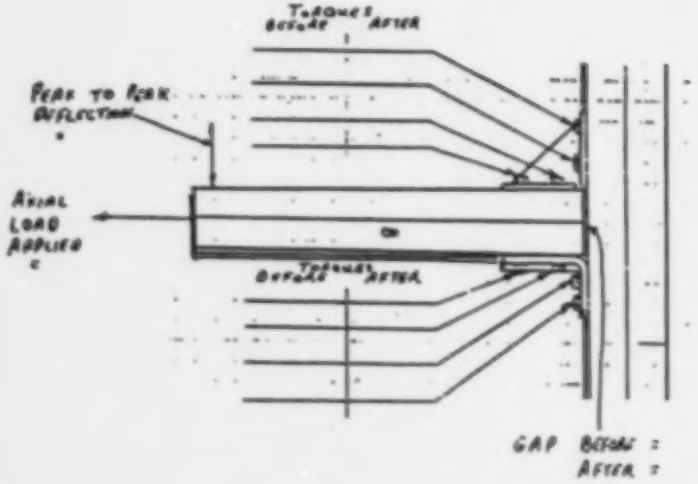
FIGURE 8

SHAKER TABLE SET-UP FOR SEISMIC TESTING OF WALL MOUNTED BRACKETS. THE CABLE TRAY SHALL BE LOADED AS DESCRIBED IN THE TEST PROCEDURE. THE MOUNTING STRUT "A" SHALL BE DEFORMED FOR TESTS ON HSR-X AND HSE-X SAMPLES. HSC-X SAMPLES SHALL BE AS RECEIVED MATERIAL.

ATTACHMENT B

SAMPLE NO.: _____ JOB NO: ( )- -

PROCEDURE: _____ PARAGRAPH NO.: _____



RECORDED BY: _____ DATE: _____

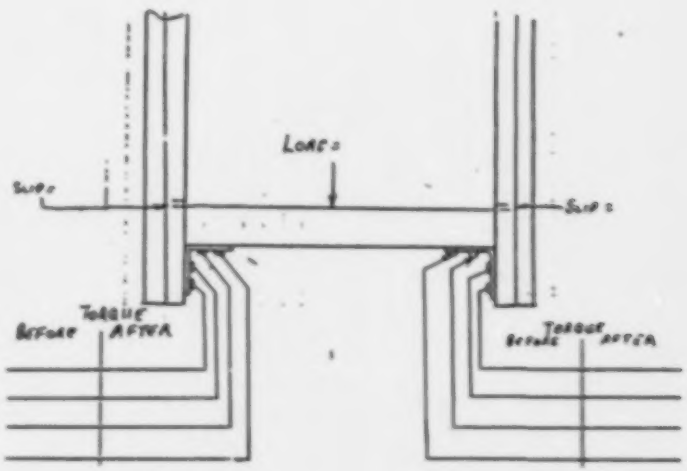
APPROVED BY: _____ DATE: _____

NOA WRITTEN: _____

ATTACHMENT C

SAMPLE NO.: _____ JOB NO: ( )- -

PROCEDURE: _____ PARAGRAPH NO.: _____



RECORDED BY: _____ DATE: _____

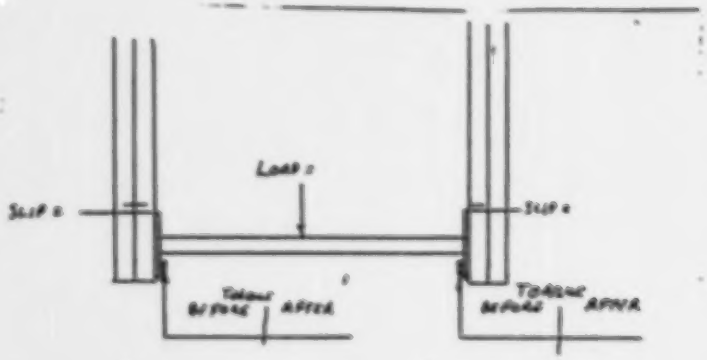
APPROVED BY: _____ DATE: _____

NOA WRITTEN: _____

ATTACHMENT D

SAMPLE NO.: _____ JOB NO: [ ]- -

PROCEDURE: _____ PARAGRAPH NO.: _____



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RECORDED BY: _____ DATE: _____

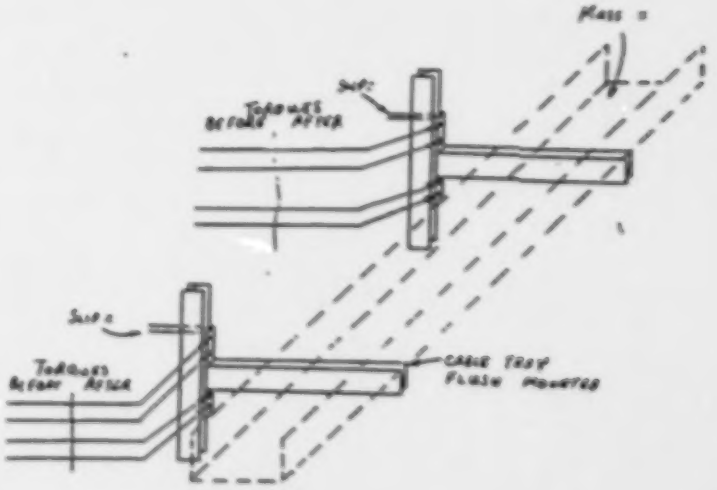
APPROVED BY: _____ DATE: _____

NOA WRITTEN: _____

ATTACHMENT E

SAMPLE NO.: _____ JOB NO: [ ]- -

PROCEDURE: _____ PARAGRAPH NO.: _____



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RECORDED BY: _____ DATE: _____

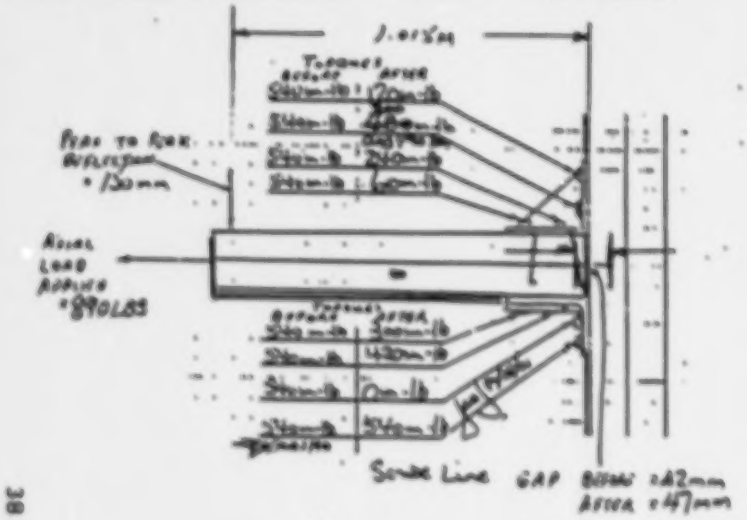
APPROVED BY: _____ DATE: _____

NOA WRITTEN: _____

ATTACH PLOT 8

SAMPLE NO.: HC1 JOB NO: 91-21-001

PROCEDURE: 91-21-001 PARAGRAPH NO.: 6.2.6



Corrosion / 445 LB = 2m-LB 445 m-LB = 540m-LB

1LB = 4.448222 N 400N = 899.2 LB

Residual torques measured as Break off Torque

RECORDED BY: D. Austin DATE: Aug 1/90

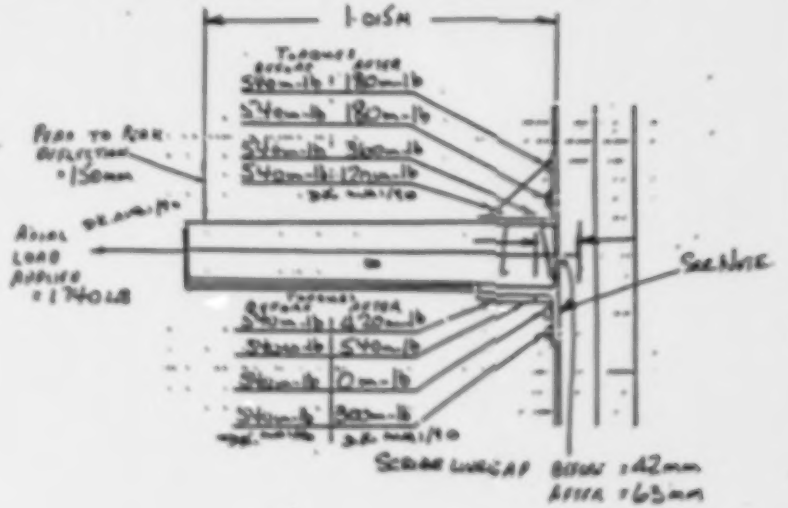
APPROVED BY: [signature] DATE: Aug 1/90

NCR WRITTEN:

ATTACH PLOT 8

SAMPLE NO.: HC1 JOB NO: 91-21-001

PROCEDURE: 91-21-001 PARAGRAPH NO.: 6.2.6



Note: deformation of vertical strut

Residual torques measured as Break off Torque

RECORDED BY: D. Austin DATE: Aug 1/90

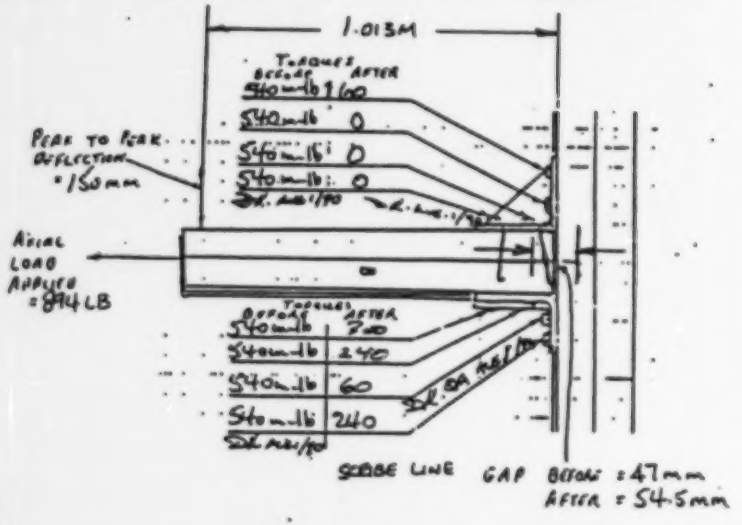
APPROVED BY: [signature] DATE: Aug. 1/90

NCR WRITTEN:

ATTACHMENT B

SAMPLE NO.: HC2 JOB NO: 89-21-001

PROCEDURE: 89-21-001 PARAGRAPH NO.: 6.2



Residual Torque measured as back off

RECORDED BY: D. Auston DATE: Aug 1/90

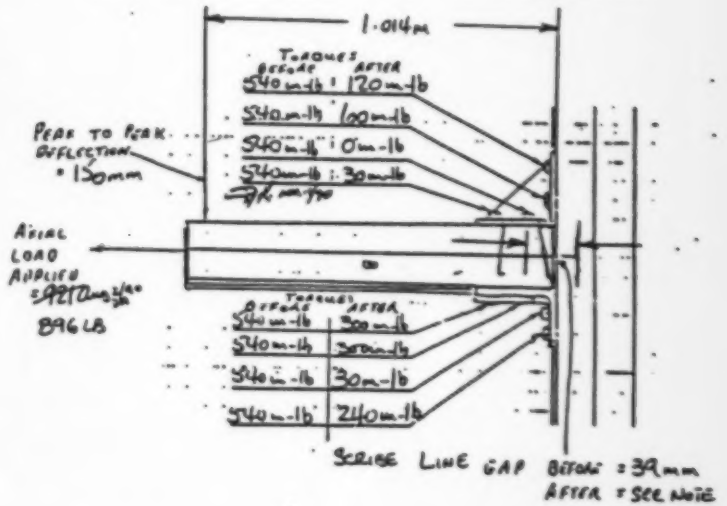
APPROVED BY: [signature] DATE: AUG/1/90

NOA WRITTEN: _____

ATTACHMENT B

SAMPLE NO.: HC3 JOB NO: 89-21-001

PROCEDURE: 89-21-001 PARAGRAPH NO.: 6.2



Note: After only 27 cycles the slippage in the load carrying direction was 22½mm.

Residual Torque measured as back off.

RECORDED BY: D. Auston DATE: Aug 2/90

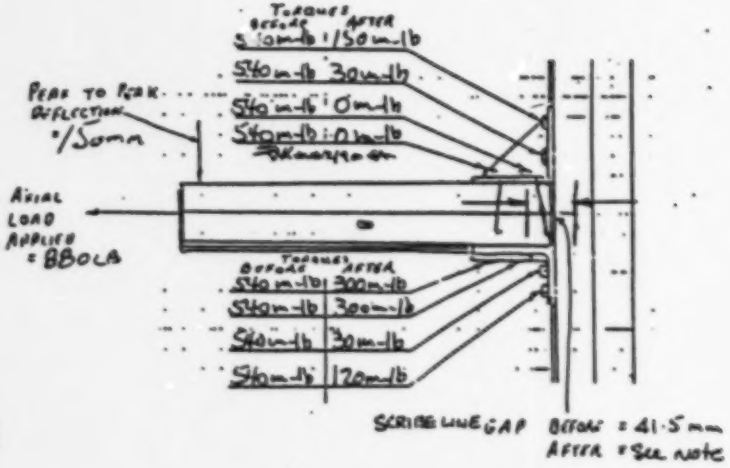
APPROVED BY: [signature] DATE: AUG 2 1990

NOA WRITTEN: _____

ATTACHMENT B

SAMPLE NO.: HC4 JOB NO: 891-21-001

PROCEDURE: 89-21-001 PARAGRAPH NO.: 6.2



40

After 27 cycles the total slippage in the load carrying direction was 24.5mm

Residual torque measured as back off

RECORDED BY: D. Austin DATE: Aug 2/90

APPROVED BY: [signature] DATE: Aug. 2/90

NDA WRITTEN: [signature]

91-48

NOTICE OF ANOMALY

DATE: Aug 13/90

Notice No.: 1 P.O. No.: NA Contract No.: NA

Customer: DARLINGTON ENGINEERING Job No.: (89)21-001

Notification Made To: T. QUANT Notification Date: Aug 13/90

Notification Made By: D. A. BLACK Via: TELEPHONE

Category: __ Specimen __ Procedure __ Test Equipment __ Other

Date of Anomaly: Aug. 3/90

Part Name: CABLE TRAY SUPPORT Part No.: CANSTRUT NUTS STOCK CODE 391A5542

Test: LOAD TESTING I.D. No.: HC-3 & HC-4

Specification: 89-21-001 Paragraph No.: 6.6 & 5.0

REQUIREMENTS: EACH SAMPLE SHALL BE MOUNTED AND TESTED AT THE SAMPLES "LOAD LIMIT". SAMPLES ENDING IN -2, -3 AND -4 SHALL BE CAPABLE OF CARRING THE TEST LOAD WITHOUT SLIPPAGE (GREATER THAN 20 mm)

DESCRIPTION OF ANOMALY: SAMPLES HC-3 AND HC-4 SLIPPED GREATER THAN 20 mm.

DISPOSITION - COMMENTS - RECOMMENDATIONS: PLACE THE TESTING ON HOLD UNTIL PROBLEM RESOLVED.

Verification:

RECEIVED AUG 14 1990 CONTROLLED COPY OF

PERMANENT __ NON-PERMANENT X

NA
Test Witness

NA
Representing

Quality Assurance 8/14/90

D. A. Black Aug 13/90
Project Engineer

Program Manager Aug 13/90

T. QUANT 90.08.13
Interdepartmental Coordination

NA
Interdepartmental Coordination

FORM NO. 15.1-1, 12/85

APPENDIX B

RECORDS FROM SELECTED MEETINGS

968-9333:5
rev. 85-11

minutes of meeting

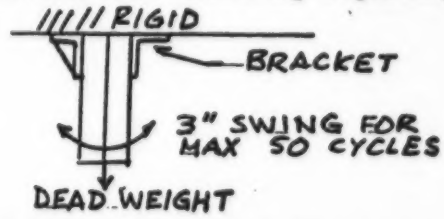
ended by			date	file reference
C.V. Robinson	Darl. E&C		August 27, 1990	NK38-57400T2
L. Sonnenburg	Darl. E&C			
C.M. Alexander	Civil H17 F24			
M.H. Thompson	Elect. H16 G26	cc: J.C. Lee	H17 C21	
D.A. Black	Research KB214	W. Duckitt	H16 A12	
B. Teper	KB223			
T. Quant	Elect. H16 F26			

subject

Darlington GS-A
Seismic Tests of Cable Tray Support

summary of minutes

1) The test was demonstrated at the Research Laboratory regarding the failure moods of hanger support.



After less then 20 cycles of swinging, the double strut hanger started to slide under a constant loading. The failure is due to the fact that:
(a) the hanger bracket is not fastened by a through bolt such as H3000 ass'y, and
(b) the teeth on the nut failed to stop the strut from sliding.

C.V. Robinson claims that there isn't sufficient bracket material around the bend to allow elastic deformation during the lateral swing of the strut.

2) The test set up at Darlington Site is different from the LAB. In the LAB, the double strut hanger is attached to a rigid structure, on which the stress is applied directly to the bracket ass'y. While the test set up at Site, the double strut hanger is attached to a long piece of horizontal double strut with the two ends welded to a rigid structure, the horizontal double strut will dampen the stress acting on the hanger bracket ass'y.

3) It was agreed in the meeting that the present test objective needs to be expanded to include the various factors involved in the actual installation at site. The main objective is to find out the realistic amount of reworks required, such factors involved will be the "G" values at different areas, and the tray loading.

Action: Research to visit site on Sept. 5, 1990. Within one week after the site visit, research, to establish test program with Darlington Engineering.

location of meeting		date	
	800 Kipling Ave. Room KB202	August 21, 1990	
		time	1:10 p.m.
prepared by	name	tel. local	
	T. Quant	6826	

91-48

attended by					date	file reference
C.M.	Alexander	Civil	J.W.	Forest	91 01 16	NK38-57400 P
L.	Sonnenburg	Darl. E&C	B.	Teper		
C.V.	Robinson	Darl. E&C	W.	Duckitt		
M.H.	Thompson	H16	T.	Quant		
R.	Kappe	Civil	cc:	J.C. Lee		
J.	Tang	Civil		W.B. Stewart		
D.A.	Black	Research				

Research
Research
H16
H16
Civil
H16

subject

Darlington G.S. "A"
Seismic Tests of Cable Tray Support with Canstrut Brackets and Canstrut Nuts

summary of minutes

GENERAL DISCUSSION

1. Construction has inspected Units 1 and 2 Reactor Vault, and all the misaligned Canstrut nuts have been checked and corrected. For outside Reactor Vault, there are about 6% not corrected misaligned Canstrut nuts.

2. According to Civil, chances of cable tray failure in conventional way of installation is rare, and therefore 6% bad installation is not serious. However, there is still a need to know how bad is the canstrut nut through Seismic testing.

3. Research said that damping factor between 10% to 20%, the changes in displacement are small. Since most of the tray installations are short, straight run with "tee" and 90 degrees turns, the realistic seismic frequency could be in the range of 8 to 10 hertz. The seismic frequency have been lowered for those long straight run trays. Civil required some preliminary exploratory tests from Research to find out at what frequency and loading the Canstrut nuts will fail in order to come up with test parameters.
(The conservative tests done in the past used 0.5 - 2.7 Hz 75 mm displacement at 5% damping factor. Research suggest to use 8.5 Hz 6 mm displacement at 10% damping factor).
Both Civil and Research agreed that each test can be terminated after 50 cycles.

location of meeting	location	date	time
	H06 "B2"	90 01 09	1:05 p.m.

prepared by	name	tel. local
	T. Quant	6826

Minutes of Meeting cont'd

CONCLUSIONS

1. Research will conduct a "hammer" test to find out the natural frequency of a group of representative designated trays suggested by Electrical. Research will provide a tabulated grouping of these "designated" trays.

   ACTION: Research, Electrical, Construction.

2. Research to perform a crude test on Canstrut bad nuts, to find out at what frequency and loading the nuts start to fail.

   ACTION: Research

3. Along with above information, Research will submit the new test plan before Jan 31, 1991, to W. Duckitt for Civil to review and comment on the test parameters.

   ACTION: Research, Electrical, Civil

4. Research will submit to W. Duckitt a comprehensive cost and test schedule for the complete program.

SUPPLEMENTARY INFORMATION

SCN 391A5542 Nut for supporting cable tray.

Nov/83	Canstrut ----------	delivered	3,410,000 pcs
Jun/88	Canstrut ----------		160,000
	(Outstanding ordered to be cancelled 320,000 pcs, under quarantine 60,000 pcs)		
Jun/88 - May/90	Unistrut ----------		1,100,000
		Total	**4,670,000 pcs**

Estimated issued:

Unit 0 - 900,000 pcs	Canstrut nut
Unit 2 - 900,000	Canstrut nut
Unit 1 - 900,000	Canstrut nut
Unit 3 - 500,000	Canstrut nut
Unit 3 - 400,000	Unitstrut nut
Unit 4 - 900,000	Unitstrut nut

We were also assuming that the quality of Canstrut nuts started deteriorating after Burndy's Division was sold to Canstrut in 1985.